DEVELOPMENT OF INFERENTIAL METHODS FOR DYNAMIC FUELS MODELING IN A CONIFEROUS FOREST TYPE

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Final Report

16-839-CA

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0.2. Preface

This paper constitutes the final report to Cooperative Aid Agreement No. 16-839-CA between the Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, Colorado, and Systems for Environmental Management, P.O. Box 3776, Missoula, Montana. Study funds were provided by the National Fuels Inventory and Appraisal Project, Peter J. Roussopoulos, Project Leader, and the study was performed by Collin D. Bevins, Principal Investigator.

1. INTRODUCTION

1.1. Study Purpose

The principal motivation for a National Fuel Inventory and Appraisal System is that it will aid forest managers in assessing the possible fire-related consequences of alternative land management prescriptions and activities. These consequences involve changes in fuel condition, and hence, changes in fire behavior potential, both as a response to management activity and as indirect ecosystem responses to perturbation. The construction and validation of models representing the dynamic behavior of wildland fuels can provide a mechanism in integrating fire management considerations into land use planning.

Ideally, the models would be process-oriented, determining fuel conditions through the rates at which fundamental physical and biological processes occur. However, the urgency of need for this information precludes a first principles approach at this time in favor of an empirical one.

It is the purpose of the study to develop an empirical method of inferring properties of fuel communities from existing or readily obtainable inventory data. The approach developed shall represent or predict both short and long term changes in wildland fuel conditions in the absence of management activity. The study objective is to develop and demonstrate methods of dynamic fuel modeling in a specific forest overstory cover type.

1.2. Study Approach

Several preliminary questions concerning the basic underlying nature of forest fuel populations need to be answered before the study objective can be

realized:

(1) What are the characteristics of stand mean forest fuel populations throughout the coniferous forests of the western U.S.?

(2) What are the characteristics of stand mean forest fuel populations sampled from a specific overstory species but with differing stand and site factors?

-- Does sampling from a specific overstory type reduce population variance?

-- Are the differences in population parameters between a single overstory type and the pooled population of all overstory types significant statistically? Are the differences significant with respect to forest management practices and land use planning?

(3) How useful are associated stand and site factors in controlling the observed variance in stand mean fuel populations for a single overstory type?

-- Which stand and site factors are the most significant covariates with stand mean fuel estimates?

-- If significant relationships can be inferred between fuels and stand and site factors, what is the underlying form (linear or curvilinear) and nature (additive or multiplicative) of the relationship?

-- If no significant relationships can be inferred, why not?

(4) After controlling for significant stand and site covariates, what is the distribution and variance of forest fuels within stands?

Solutions to the questions will also begin to answer the broader question concerning the feasibility of dynamic forest fuel modeling based upon empiri-

cal data, and perhaps provide some information on the utility of such models in forest management and land use planning. The study is therefore broken into 2 separate parts. The first part is an attempt to answer questions (1) through (4) to provide background information on the empirical data base and provide direction in selecting an appropriate method of natural fuels modeling. The second part of the study is concerned with the construction and analysis of the resulting fuel models.

2. SAMPLE DATA

2.1 Stand Mean Fuel Data

Questions (1) through (3) in the previous section concern themselves with the distribution of stand mean forest fuel estimates. Statistically sound analyses and inferrence methods require a random sample of the population under investigation. The first such random sample of stand mean forest fuel estimates has been conducted as part of the U.S.D.A. Forest Service Northern Region's Stand Examination - Forest Inventory procedure. The use of stand mean fuel estimates is important to the analyses in that, under the Central Limit Theorem, the sample population will approximate the normal distribution, permitting the use of normal parametric statistical techniques.

The Stand Examination - Forest Inventory was conducted on all Northern Region national forests from 1973 through 1979 (figure 1). The boundaries and areas of all nonwilderness stands within each national forest were determined from aerial photos. Stands were then selected for on-the-ground examination with probability-proportional-to-size as described by Stage and Alley (1972). The sample design permits unbiased inferrences to be made from the sampled stands and applied to the entire national forest.

Each selected stand was systematically sampled throughout its boundaries. Sample points were located on a 5 x 10 chain grid resulting in a sample intensity of approximately 1 point per 5 acres.[1/] Sample point data were keypunched and summarized on a stand basis. The stand mean estimates were available for use in the study, but the point by point information was not.

The type and amount of information recorded within a stand varied due to fiscal constraints and other reasons unknown. The quantity and quality of stand information is presented by national forest in table 1. All study

Figure 1 : U.S.D.A. Forest Service Northern Region National Forests

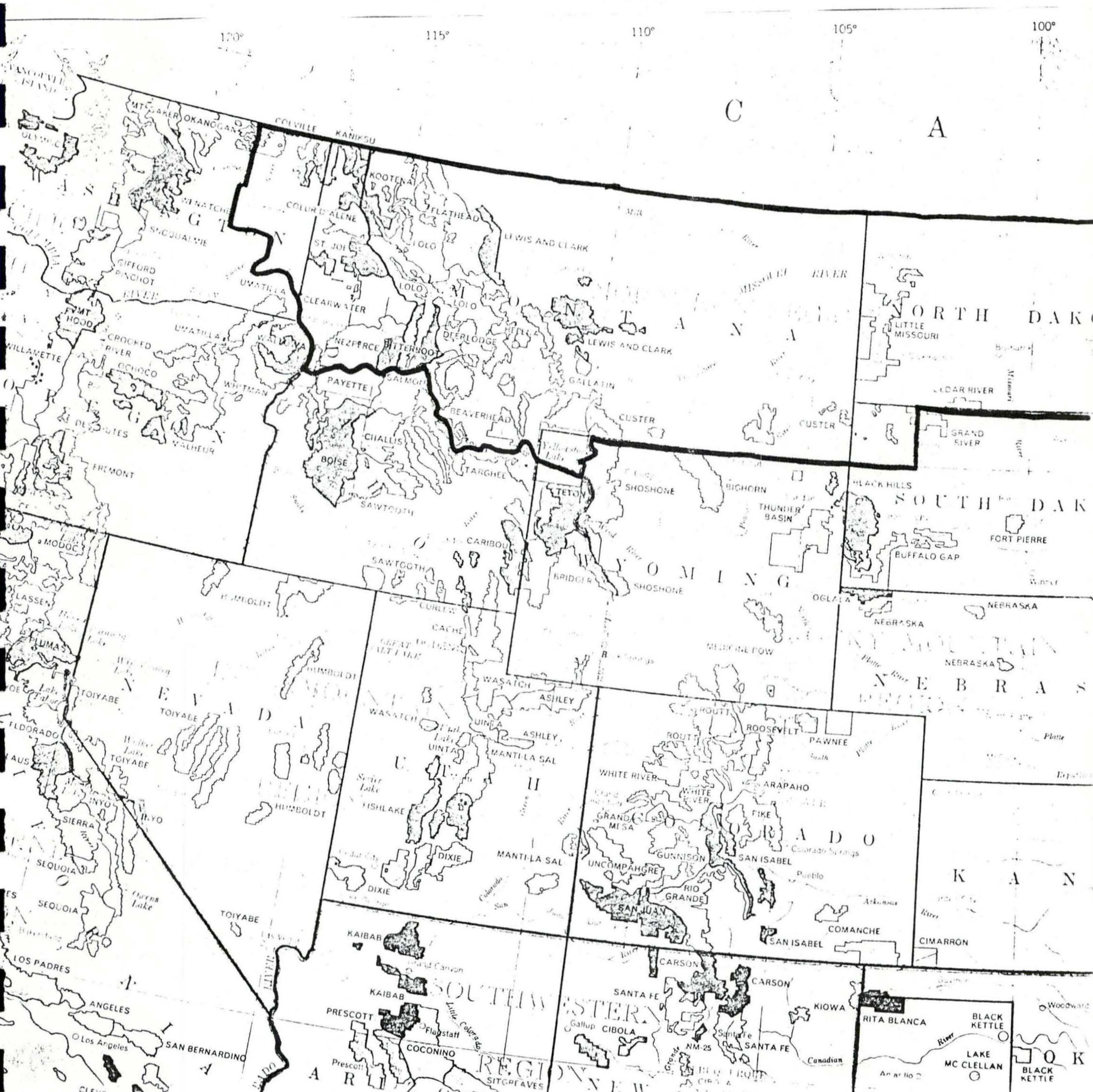

Table 1 : Northern Region Stand Examination-Forest Inventory sample stands by national forest and information content

National forest	inventory total	.... with fuels data	predominantly Douglas-fir	exclusively Douglas-fir
	- - - - - -	number of	sample stands	- - - - - - - -
Bitterroot	341	157	97	29
Clearwater	365	339	66	9
Colville*	344	334	72	0
Custer	258	232	16	0
Deerlodge	491	478	94	0
Flathead	613	552	97	21
Gallatin	354	309	72	0
Helena	396	358	113	0
Kaniksu	180	171	10	0
Kootenai	528	517	156	37
Lolo	583	570	214	41
Nezperce	300	273	81	0
St. Joe	218	67	22	8
Region total	4971	4357	1100	145

* Transferred to Region Six on July 1, 1974.

analyses assumed those stands with mean fuel estimates to constitute a random sample of the national forests inventoried.

The following fuel measurements were taken at each sample point within those stands whose fuels were inventoried:

-- number of 10-hour fuel particle intersections along the first 6.8-feet of a 27.2-foot transect,

-- number of 100-hour fuel particle intersections along the first 6.8-feet of a 27.2-foot transect,

-- diameter of all 1000-hour sound fuel particles at their point of intersection with the 27.2-foot transect,

-- diameter of all 1000-hour rotten fuel particles at their point of intersection with the 27.2-foot transect,

-- duff layer depths to the nearest 0.1-inch measured at the 1.0- and 6.8-foot mark of the 27.2-foot transect, and

-- percent slope of the 27.2-foot transect.

The fuel measurements were converted to the following fuel characteristics after Brown (1974)[2/]:

-- stand mean 10-hour fuel load (tons per acre),

-- stand mean 100-hour fuel load (tons per acre),

-- stand mean 1000-hour sound fuel load (tons per acre),

-- stand mean 1000-hour rotten fuel load (tons per acre), and

-- stand mean duff layer depth (inches).

An additional fuel class was created by summing together the 10-, 100-, and 1000-hour fuel loads. The class will be called the 'total' dead and down fuel load class throughout the remainder of the report, even though it does not include 1-hour fuel loads.

Important stand and site factors recorded at each sample point and used in the study analyses include[3/]:

-- stand location (national forest, district, compartment, and stand number),

-- predominant forest overstory type (by species plurality),

-- stand age of the predominat forest overstory type,

-- species of the first, second, and third overstory components,

-- d.b.h. of the first, second, and third overstory components,

-- stand age of the first, second, and third overstory components,

-- stems per acre of the first, second, and third overstory components,

-- site productivity class,

-- aspect class,

-- terrain slope,

-- elevation,

-- habitat type, and

-- stand damage type and intensity class.

The following information was added from NOAA climatological summaries of the nearest year-around weather station:

-- mean annual temperature, and

-- mean annual total precipitation.

2.2 Within Stand Fuel Data

Plot by plot fuels inventory data were available to the study from the Fire in Multiple Use Management RD&A Program's fuel inventory database. The data were recorded from national forests throughout Idaho, Montana, and Wyoming. Stands were not selected for sampling according to an overall statistical design, and the sample points within each stand were located by unknown methods. Sample intensity within each stand is similarly unknown.

Fuel measurements taken at each sample point included[4/]:

- -- number of 1-hour fuel particle intersections along the first 6.8-feet of a 20.0-, 27.2-, or 35.0-foot transect,
- -- number of 10-hour fuel particle intersections along the first 6.8-feet of a 20.0-, 27.2-, or 35.0-foot transect,
- -- number of 100-hour fuel particle intersections along the first 10.0-feet of a 20.0-, 27.2-, or 35.0-foot transect,
- -- diameter of each 1000-hour sound fuel particle at the plane of intersection with the 20.0-, 27.2-, or 35.0-foot transect,
- -- diameter of each 1000-hour rotten fuel particle at the plane of intersection with the 20.0-, 27.2-, or 35.0-foot transect,
- -- transect slope,
- -- duff layer depth to the nearest 0.1-inch at the 6.8- and 13.6-foot mark of the 20.0-, 27.2-, or 35.0-foot transect, and
- -- highest particle dead and down fine fuel height, if present, at the 0.0-, 3.4-, and 6.8-foot marks of the fuel transect.

The above fuel measurements were again converted to dead and down fuel class loads after Brown (1974), mean plot duff layer thickness, and if possible, dead and down fuel bulk density (based on the highest intercept height).

The type and amount of stand and site information recorded at each sample point again varied between stands. The data recorded normally included:

- -- dominant forest overstory type,
- -- stand age,
- -- terrain slope,
- -- aspect,
- -- elevation, and
- -- habitat type.

The number of RD&A database stands and plots are summarized by national forest and dominant forest overstory type in table 2.

Table 2 : Fire in Multiple Use Management RD&A fuel inventory database

Inventory location	National forest	Total plots	Douglas-fir plots
Moose Creek	Clearwater	2138	442
Copper Queen	Bitterroot	550	296
Lower West Fork	Bitterroot	183	70
Upper West Fork	Bitterroot	47	22
Lower Hughs Creek	Bitterroot	14	7
Sawtooth Primitive	Sawtooth	277	58
Tolan Creek	Bitterroot	712	200
Spanish Peaks Prim.	Gallatin	434	88
Buck Creek	Gallatin	186	22
Powell Ranger Dist.	Clearwater	362	67
Whitecap Primitive	Clearwater	1354	396
Shoshone	Shoshone	594	185
Pattie Canyon	Lolo	105	2

3. NATURAL FUELS POPULATIONS : IMPLICATIONS FOR DYNAMIC FUEL MODELING

3.1. Pooled Stand Mean Fuel Populations

Question (1) was rephrased to directly address those coniferous forest fuel populations sampled by the Northern Region's Stand Examination - Forest Inventory procedure:

(1) What are the characteristics of stand mean forest fuel populations throughout the federally-owned nonwilderness National Forest System lands of western Montana and northern Idaho?

Summary statistics for the pooled population of 4357 sample stands of various overstories and stand and site characteristics are presented in table 3. Several observations can be made concerning the pooled populations:

- All 6 fuel populations are significantly skewed to the right.
- All 6 fuel populations have highly significant kurtosis measures.
- Population medians range from 30 to 90 percent of the means.
- Standard deviations range from 90 to 190 percent of the means.
- The 'average' (mean) Northern Region forest stand contains about 17-tons per acre of dead and down material on a 1.1-inch duff layer.
  - About 7.9-tons per acre (45 percent) of the total fuel load is large rotting fuel.
  - Another 6.5-tons per acre (40 percent) is large sound fuel.
  - The remaining 2.6-tons per acre (15 percent) is fine fuel.

An unusually large amount of variance exists in the stand mean fuel estimates. The variability within and/or between stands is apparently great enough to prevent the population of mean estimates from approaching normality,

Table 3 : Fuel population characteristics by overstory type

fuel measure	overstory type	n	mean	st.dv. (%)	skew.	kurt.*	median (% of mean)
Total dead &	All types	4357	17.05	18.45 (108)	2.96	17.76	11.90 (70)
down load	Pred. DF**	1110	14.09	14.54 (103)	2.24	7.09	9.90 (70)
(tons/ac)	Excl. DF***	145	13.79	10.86 (79)	1.71	4.02	11.00 (80)
Sound 1000-hr	All types	4357	6.47	12.29 (190)	5.76	61.65	2.12 (33)
dead & down	Pred. DF	1110	4.39	8.43 (192)	4.01	21.53	1.24 (28)
(tons/ac)	Excl. DF	145	4.23	5.53 (131)	2.40	6.59	2.07 (49)
Rotten 1000-hr	All types	4357	7.85	11.14 (142)	3.82	33.43	4.07 (52)
dead & down	Pred. DF	1110	6.86	9.91 (145)	3.12	15.13	3.32 (48)
(tons/ac)	Excl. DF	145	6.89	8.19 (119)	2.82	11.39	4.33 (63)
100-hr dead &	All types	4357	1.72	2.10 (122)	3.23	18.17	1.15 (67)
down load	Pred. DF	1110	1.75	2.16 (123)	3.50	21.73	1.17 (67)
(tons/ac)	Excl. DF	145	1.61	1.54 (96)	2.92	13.20	1.26 (78)
10-hr dead &	All types	4357	1.01	0.96 (95)	3.54	29.02	0.81 (80)
down load	Pred. DF	1110	1.09	1.03 (95)	4.51	40.70	0.93 (85)
(tons/ac)	Excl. DF	145	1.06	0.63 (59)	1.11	1.64	1.00 (94)
Duff layer	All types	4357	1.10	0.97 (88)	2.06	8.63	0.91 (83)
depth	Pred. DF	1110	1.00	0.82 (82)	1.88	6.66	0.86 (86)
(inches)	Excl. DF	145	0.96	0.65 (67)	1.06	2.03	0.90 (94)

* Kurtosis statistic scaled to zero for the normal distribution.

** Predominantly Douglas-fir

*** Exclusively Douglas-fir

as per the Central Limit Theorem, even after 4300-plus samples have been drawn.

3.2. Stand Mean Fuel Populations by Overstory Species

The 4357 stand mean samples were stratified into 14 dominant overstory species groups in an attempt to reduce pooled population variance, determine if stand mean fuel populations by overstory species approach normality, and to answer question (2). An analysis of variance of fuels between the 14 species groups showed significant* differences in all 6 fuel populations (appendix B). The stratification accounted for 12 percent of the variance in total dead and down fuel loads and 9 percent of duff layer thickness variance.

Posteriori contrasts using the Scheffe procedure failed to identify unique groupings of dominant overstory species even when significance levels were relaxed to 0.50. Related species appear to have similar populations, however, and the following groupings were suggested after ranking populations means:

(1) Western red cedar - western hemlock (35 plus tons per acre total dead and down fuel load)

(2) Spruce - true firs (25- to 35-tons per acre)

(3) Lodgepole pine - Douglas-fir (15- to 25-tons per acre)

(4) Marginal timber lands; noncommercial forest, whitebark - limber pine (10- to 15-tons per acre)

(5) Ponderosa pine - western larch (5- to 10-tons per acre)

(6) Hardwood - aspen (5- to 10-tons per acre)

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* The use of the statistical term "significance" throughout this report refers to a probability level of $p < 0.05$.

3.3. Douglas-fir Stand Mean Fuel Populations

3.3.1. All Stands

The majority of the stand mean sample data are from interior Douglas-fir (Pseudotsuga menziesii var. glauca) stands (table 1). This overstory species was selected for further fuels analysis because it accounts for one-fourth of all forested areas in the Northern Region and has a correspondingly high number of sample stands available (n = 1110).

Stand mean fuel populations for Douglas-fir stands (table 3) show that:

- -- Skewness in the 6 fuel populations, while reduced, remains significant.
- -- Kurtosis in the 6 fuel populations, while reduced, remains significant.
- -- Population medians remain at 30 to 90 percent of the means, just as in the pooled population.
- -- Standard deviations remain at 80 to 190 percent of the means, just as in the pooled population.
- -- The 'avereage' (mean) Douglas-fir stand contains about 14-tons per acre of dead and down fuel on top of a 1.0-inch duff layer.
  - -- About 6.0-tons per acre (50 percent) of the total fuel load is large rotting fuel.
  - -- Another 4.4-tons per acre (30 percent) is large sound fuel.
  - -- The remaining 2.7-tons per acre (20 percent) is fine fuel.

An analysis of variance between fuels from Douglas-fir and those of all other overstory species shows statistically significant differences in all but 100-hour fuel load. The differences appear to be insignificant, however, with respect to forest management practices (refer to table 3).

3.3.2. Pure Stands

In a further attempt to reduce population variance, summary statistics were again computed for 145 pure Douglas-fir stands meeting the following criteria:

(1) The first and second overstory components, if present, must be interior Douglas-fir.

(2) The stand must not have any recorded management history.

(3) More than 5 sample points must have been used in estimating the stand mean fuel values.

The restrictions markedly reduced population skewness and kurtosis, although both remained significant (table 3). Medians more closely approached the means and percent standard deviations were reduced by 20 to 60 percentage points. An analysis of variance between the 965 mixed stands and 145 pure stands showed no significant differences in fuels.

The fuel populations therefore appear to more closely approximate normality as more restrictions are placed on the type and composition of the overstory.

3.4. Douglas-fir Stand Mean Fuels and Stand-Site Factor Relationships

3.4.1. Sample Data

Question (3) concerns the relationships between stand mean fuel parameters and their associated stand and site factors. If stand and site characteristics can be used to control a significant amount of the variance in fuels estimates, they may be used to model or predict Douglas-fir fuels using classical regression analysis techniques. The 145 sample means from pure Douglas-fir stands

were used in this portion of the analysis because their fuel populations more closely approximate normality, have lower variance, and can be expected to have fewer confounding factors than multiple-species overstories. To further reduce undesired sample variance, the following additional crietria were set in the selction of sample data:

(4) All important stand and site factors must have been recorded, i.e., those listed in section 2.1 and in table 4.

(5) Stand age must be at least 20 years.

The stand age limitation was imposed, first, to discard those stands where stand age was not recorded and second, to mitigate the problem of the previous stand's unknown influence on the fuel condition of the young stand succeeding it (Brown 1975). This left 129 sample stands for the analysis of fuel and stand-site factor relationships.

3.4.2. Pearson Correlations

Simple correlation coefficients were computed between the 6 fuel measures and several stand and site factors for the 129 sample stands (table 4). The results indicate that:

-- Simple correlations between fuels and stand-site factors are quite low. Most r's are in the 0.05 to 0.20 range with a maximum r of 0.35.

-- Most correlation coefficients are not significant even though the 5 percent significance level corresponds to an r of only 0.174.

-- Stand density and site productivity are the only factors with significant correlations with 3 or more fuel measures.

-- The square of the correlation coefficient indicates that stand density accounts for only 1 to 12 percent of the fuel variation, and site pro-

Table 4 : Pearson's correlations (simple r) between forest fuel values and stand - site factors

Stand or site factor	Total D&D	Duff depth	Fuel load sound	Fuel load rotten	Fuel load 100-hr	Fuel load 10-hr
Stand age (years)	-.050	-.135	.100	-.059	-.248**	-.232**
ℓn(stand age)	-.097	-.119	.101	-.115	-.269**	-.239**
Productivity (ft^3/yr)	.201*	.187*	.058	.180*	.181*	.189*
ℓn(productivity)	.177*	.160	.097	.132	.157	.188*
Stems per acre	.354**	.096	.250**	.249**	.294**	.212*
ℓn(stems per acre)	.297**	.221*	.127	.269**	.164	.196*
D.b.h. (inches)	-.177*	-.121	-.051	-.167	-.135	-.125
ℓn(d.b.h.)	-.217*	-.046	-.094	-.193*	-.157	-.091
Basal area (ft^2/ac)	-.002	.120	-.018	.013	-.054	.051
ℓn(basal area)	.072	.263**	.052	.057	-.017	.131
Live volume (ft^3/ac)	.010	.329**	-.048	.045	-.046	.130
ℓn(live volume)	-.037	.346**	-.116	.043	-.101	.076
Dead volume (ft^3/ac)	.166*	.148	.275**	.045	-.043	-.040
ℓn(dead volume)	.144	.123	.241**	.045	-.071	-.049
Damage intensity (%)	-.015	.052	-.081	.046	-.088	.074
Cosine (Aspect - 45°)	-.033	-.080	-.074	.017	-.038	-.044
Slope (%)	-.035	.122	-.129	.014	.070	.175*
Elevation (feet)	-.113	-.130	-.078	-.006	-.356**	-.312**
Mean annual temp.	.274**	.088	.045	.094	.025	.085
Mean annual precip.	.110	-.048	.130*	.182**	.004	.184**

* Significant at $p < 0.05$

** Significant at $p < 0.01$

ductivity controls 1 to 4 percent of the variance.

-- Stand age has significant correlations only with fine fuel loads. Age accounts for as little as 0.2 percent of the variance in total dead and down fuel load, and as much as 6 percent of the 100-hour fuel load variance.

3.4.3. Forest Fuels and Stand Age

As implied by the term 'dynamic fuel modeling', stand age is a factor of particular interest in natural fuel modeling. It is a commonly accepted notion that fuels conditions change throughout the lifetime of a stand. The complexity of factors affecting these changes has been discussed by Brown (1975) for the lodgepole pine community. The special interest in stand age as a fuel covariate may be due in part to its relationship to many stand characteristics (stem d.b.h., density, basal area, mortality, competition, etc.) that are more difficult to measure or estimate in the field, but probably have a more direct or causal relationship with fuel conditions.

A series of partial correlations (zero to third degree) were computed between stand age and fuels controlling for all combinations of mean stand d.b.h., density, and basal area (table 5). The resulting partial correlation coefficients indicate that stand density, d.b.h., or basal area, either alone or in combination, neither mask nor enhance the fuel - age relationship. Furthermore, stand age appears to be totally independent (at least linearly) of the 3 stand factors. Possible causes of the poor relationship between fuels and stand age include:

-- Stand age is related to the stand fuel condition only through intervening stand-site factors and their rates of change.

-- The relationships between stand age and stand factors are known from

Table 5 : Forest fuel partial correlations with stand age controlling for stand density, d.b.h., and basal area

Partial corr. order	Controlled variables	Total load	1000-hr sound	1000-hr rotten	100-hr	10-hr	duff depth
0	none	-0.050	0.100	-0.059	-0.248*	-0.233*	-0.135
1	density	-0.040	0.113	-0.052	-0.249*	-0.231*	-0.132
	d.b.h.	-0.056	0.097	-0.059	-0.267*	-0.241*	-0.138
	basal area	-0.041	0.125	-0.062	-0.246*	-0.226*	-0.137
2	dens., d.b.h.	-0.000	0.095	0.012	-0.261*	-0.228*	-0.137
	dens., b.a.	-0.054	0.126	-0.086	-0.245*	-0.229*	-0.146
	d.b.h., b.a.	-0.050	0.125	-0.078	-0.221*	-0.226*	-0.198*
3	density, d.b.h., and basal area	-0.009	0.121	-0.028	-0.221*	-0.218*	-0.192*

* $p < 0.05$

the silvicultural literature to be nonlinear.

-- The interrelationships between stand factors alone are known to be nonlinear and complex.

-- Mean stand age, density, d.b.h., and basal areas are often difficult to measure, have high intra-stand variance, and therefore have a certain amount of sample variance and error associated with them.

-- Stand age is often an insufficient indicator of the successional stage of a particular stand, especially in the absence of stand history information.

-- Fuel parameters most probably have variable first deriviatives with respect to time, and furthermore, the signs of the derivatives probably change one or more times during the lifetime of a stand.

3.4.4. Forest Fuel Relationships with Stand - Site Factors

Stepwise linear regressions were performed between the 6 fuel measures and stand and site factors listed in table 4. Independent variables included the untransformed stand and site factors, their natural logarithm transformations, and their squared terms. The purposes of the procedure were to:

-- Determine the order in which independent variables are entered into the least squares equation, and therefore their importance in controlling fuel variance.

-- Determine the statistical significance of each stand and site factor.

-- Determine if relationships between fuels and associated stand and site factors are linear or nonlinear.

-- Determine the overall variability in forest fuels that can be accounted for by sets of stand and site factors, and therefore the potential

of those factors as fuel predictors in regression-type fuel models.

Table 6 lists those stand and site factors which are significant in controlling variance in stand mean fuel values. The table suggests that:

-- Site productivity and stand density are the most important covariates with forest fuel measures, especially dead and down loads.

-- Basal area and stand age make an additional minor contribution to the controlled variance and are most important in the fine fuel loads and duff layer thickness regressions.

-- Curvilinear relationships may exist between forest fuels and stand density and age.

-- Less than 20 percent of the variance in stand mean fuel values is accounted for after all significant independent variables have been entered into the regression equations.

Two more sets of regressions were performed to confirm the above observations. The first set used site productivity, stand density and its natural logarithm transformation, and stand age and its natural logarithm transformation as independent variables. The second set replaced the 2 logarithm transforms with squared terms.

The regression set using squared terms for stand density and stand age yielded higher r^2's with fuel loads than the set using natural logarithms. The fuel load regressions indicate that:

-- Site productivity and stand density are the most important covariates with Douglas-fir fuel loads (table 7), explaining 10 to 20 percent of the variance.

-- Stand age is significant only in the fine fuel loads and controls only 1 to 5 percent of the variance (table 8).

Table 6 : Significant ($p < 0.05$) stand and site covariates with Douglas-fir stand mean fuel estimates

fuel type	total dead and down	duff depth	1000-hr sound	1000-hr rotten	100-hr	10-hr
Significant covariates	density	ℓn(ba)	density	density	$density^2$	$density^2$
	product.	age^2		product.	ℓn(age)	ℓn(age)
	d.b.h.				density	ℓn(ba)
r^2	0.160	0.152	0.063	0.100	0.183	0.147

Table 7 : Site productivity, stand density, and stand age as covariates with Douglas-fir stand mean fuel estimates

entered at step number	total dead and down	duff depth	1000-hr sound	1000-hr rotten	100-hr	10-hr
1	density*	product*	$density^2$*	density*	$density^2$*	$density^2$*
2	product.*	b.a.*	age	$density^2$*	age*	age*
3	age	ℓn(b.a.)*	density	product.*	density*	product.*
4	age^2	age*	product.	age	product.*	age^2
5	$density^2$	ℓn(age)	age^2	age^2	age^2	density
r^2 of sig. covariates	0.160	0.191	0.096	0.132	0.229	0.142
r^2 of all covariates	0.176	0.191	0.120	0.162	0.305	0.150

Table 8 : Douglas-fir stand mean fuel regression r^2's apportioned by independent variables

Independent variable	total dead and down	1000-hr sound	1000-hr rotten	100-hr	10-hr	duff depth
Stand density and density^2	0.126	0.102	0.105	0.222	0.063	0.041
Site productivity class	0.034	0.002	0.027	0.031	0.033	0.035
Stand age and stand age^2	0.016	0.016	0.030	0.052	0.053	0.019
Total r^2	0.176	0.120	0.162	0.305	0.150	0.095
Basal area and ℓn(b.a.)						0.124
Site productivity class						0.020
Stand age and ℓn(stand age)						0.047
Total r^2						0.191

-- The relationship between stand mean fuel loads and stand density is curvilinear.

The regression set using site productivity, basal area and its natural logarithm transformation, and stand age and its log transform accounted for the most variance in duff layer thicknesses, 19 percent (tables 7 and 8). Duff layer thickness appears to have a curvilinear relationship with basal area, and once again stand age and its square make only a minor contribution to the controlled variance.

3.5. Douglas-fir Within-Stand Fuel Populations

Two important observations can be made from the foregoing analyses:

(1) An extremely high degree of variance exists in stand mean fuel populations.

(2) All associated stand and site factors together account for less than 20 percent of the measured variance in fuels from pure Douglas-fir stands with no known management history.

The within-stand fuel populations were examined to determine what influence they have over the stand mean populations (question (4)). The Fire in Multiple Use Management RD&A Program fuels database was used to compute population moments from 47 Douglas-fir stands of all ages and of indeterminant stand density, d.b.h., and basal area (appendic C). A summary of the stand by stand fuel moments (table 9) indicates that:

-- Fuel loads and duff layer thicknesses are significantly skewed to the right, as are the natural logarithm transformations.

-- A major population mode exists at zero for all fuel measures.

-- Fuel load medians have a low, narrow range of 0.0 to 0.6-tons per acre for all fuel categories.

Table 9 : Summary of Douglas-fir within-stand fuel population skewness statistics[1/]

Fuel type	All data n	All data x	All data $\ell n(x+1)$	Nonzero data only n	Nonzero data only x	Nonzero data only $\ell n(x)$	P(0)[2/]
1-hr load	671	1.361*	1.164*	592	1.241*	1.057*	0.118
10-hr load	671	1.215*	0.575	473	0.916	0.448	0.295
100-hr load	671	1.148*	0.544	295	0.576	0.297	0.560
1000-hr sound	671	1.890*	1.426*	236	0.480	0.030	0.648
1000-hr rotten	671	1.722*	1.130*	270	0.667	0.214	0.598
duff layer depth	671	0.861	0.245	647	0.831	0.251	0.036

* $p < 0.050$

1/ Table values are average skewness statistics from 47 Douglas-fir stands weighted by the number of plots per stand.

2/ P(0) = estimated probability of a plot having a zero fuel value.

When the sample is restricted to those plots with non-zero fuel measures, we find (tables 9 and 10):

- -- Skewness remains significant only for 1-hour fuel loads.
- -- The lognormal transformation removes significant skewness from all populations except the 1-hour fuel load.
- -- The 100-hour and 1000-hour fuels are present in only one-third to one-half of the sample plots.
- -- Secondary non-zero modes emerge but remain far to the left of the mean.
- -- Population medians increase from 0 to 50 percent of the means.
- -- Percent standard deviations are markedly reduced.

The results suggest that within-stand fuels are contageously distributed throughout the stand (at least on the scale at which they were measured) and have bimodal distributions with the major mode at zero. This provides a partial explanation of the high variance observed in stand mean fuel populations; the stand mean is not a representative nor stable measure of the stand's bimodal fuel condition. Factors contributing to the high variability and bimodality of within-stand fuel populations include:

- -- True fuel contagion and inherent spatial variability;
  - -- Pruned needles and branches tend to accumulate beneath crowns and not between them.
  - -- Fallen trees and their branches represent clumped fuels.
  - -- Trees tend to die and fall in groups as a result of some common cause of mortality, i.e., windthrow, insects, etc.
  - -- The spatial distribution of stand vegetation may be contagious.
- -- Artificial contagion and variability:

Table 10 : Summary statistics of Douglas-fir within-stand fuel populations

fuel type	data[1]	mean	median	mode	st.d.	% st.d.[2]	skew.	ℓn skew.[3]	kurt.	ℓn kurt.[3]	P(0)[4]
total dead and down	all	19.06	6.41	0.00	32.95	173%	4.39	0.18	33.26	-1.08	.000
	non-0	10.06	6.41	0.00	32.95	173%	4.39	0.18	33.26	-1.08	
1000-hour sound	all	9.01	0.00	0.00	24.81	275%	6.85	1.18	79.76	-0.03	.662
	non-0	26.67	14.91	3.45	36.76	138%	4.72	1.18	37.59	-0.03	
1000-hour rotten	all	7.37	0.00	0.00	19.78	268%	6.30	1.14	59.58	-0.04	.635
	non-0	20.18	11.19	2.07	28.53	141%	4.36	1.14	27.71	-0.04	
100-hour	all	1.73	0.00	0.00	3.17	183%	2.97	0.99	12.15	-0.29	.619
	non-0	4.55	2.78	2.78	3.65	81%	2.40	0.99	7.62	-0.29	
10-hour	all	0.94	0.65	0.00	1.20	128%	2.84	0.82	13.73	0.26	.274
	non-0	1.30	0.97	0.32	1.24	95%	2.87	0.82	13.64	0.26	
1-hour	all	0.28	0.15	0.00	0.35	125%	2.70	1.64	10.36	3.04	.070
	non-0	0.31	0.18	0.01	0.36	117%	2.67	1.64	10.05	3.04	
duff layer depth	all	1.24	0.88	0.00	1.32	106%	3.27	0.54	8.68	-0.26	.099
	non-0	1.37	1.01	0.10	1.32	96%	2.29	0.54	8.82	-0.26	

1/ n = 1855

2/ standard deviation expressed as percent of the mean

3/ skewness or kurtosis statistic for the fuels' lognormal distribution

4/ P(0) = probability of a plot having a zero fuel value

- -- Short sample transect lengths enhance the bimodality of the data. There exists a high probability that the transect will intersect no fuel particles. If fuel is present, there tends to be several intersections.
- -- The inadequacy of short transects is further aggravated by low sample intesities, resulting in stand mean estimates with high error terms.
- -- Many data collections (including the Fire in Multiple Use Management RD&A Program data) do not constitute a statistical sample.
- -- There exists an unknown amount of sample error associated with the line intersect technique and conversion of data from intersection counts to loads.
  - -- Pickford and Hazard (1977) estimated the length of fuel sample planes required to meet specified levels of precision for a simulated 'slash' fuel population of randomly oriented, uniform cylinders. Each cylinder was 12-inches in diameter and 20-feet long, with a fuel volume of 3562-cubic feet per acre. They found the estimated population variance to be lower for a given total length of transect line when fewer transects of greater length are used. They furthermore estimated that 5500-feet of intersect line was required in the simulated fuel bed to reach a 10 percent error margin with 95 percent confidence; the Northern Region fuel inventory used less than 5.5-feet of transect line per acre.

3.6. Summary of Forest Fuel Population Characteristics

(1) Forest fuel stand mean populations from all combinations of overstory species, stand, and site factors are characterized by:

-- high variance, widely dispersed, non-normal distributions,

-- highly significant skewness and kurtosis,

-- standard deviations of 90 to 190 percent of the means,

-- medians of 30 to 90 percent of the means, and

-- mean fuel values of

  -- 17.0-tons per acre of total dead and down fuel,

  -- 7.9-tons per acre of 1000-hour rotting fuel,

  -- 6.5-tons per acre of 1000-hour sound fuel,

  -- 2.6-tons per acre of fine fuels, and

  -- 1.1-inch thick duff layer.

(2) Stratification of stand mean fuel data into 14 predominant overstory species groups accounts for about 12 percent of the variance in the pooled total dead and down fuel load and 9 percent of the variance in the pooled duff depth population.

(3) Forest stands predominated by interior Douglas-fir have stand mean fuel populations characterized by:

-- high variance, widely dispersed, non-normal distributions,

-- significant skewness and kurtosis, though less than that of the pooled population,

-- standard deviations of 80 to 190 percent of the means,

-- medians of 30 to 90 percent of the means, and

-- mean fuel values of

  -- 14.0-tons per acre of total dead and down fuel,

-- 6.9-tons per acre of 1000-hour rotting fuel,

-- 4.4-tons per acre of 1000-hour sound fuel,

-- 2.7-tons per acre of fine fuels, and

-- 1.0-inch thick duff layer.

While the differences in fuel populations between Douglas-fir stands and all other overstory cover types is statistically significant, the differences are probably not significant with respect to forest management practices.

(4) Stands consisting exclusively of interior Douglas-fir have stand mean fuel populations characterized by:

-- reduced variability over that of mixed Douglas-fir stands,

-- significant skewness and kurtosis, but markedly reduced from that of mixed Douglas-fir stands,

-- standard deviations of 50 to 90 percent of the means,

-- medians of 50 to 95 percent of the means, and

-- average fuel values less than, but not significantly different from, fuels of mixed Douglas-fir stands.

(5) Pure Douglas-fir within-stand fuels populations are characterized by;

-- bimodal distributions with major modes at zero,

-- apparent nonrandom (contagious) spatial distributions,

-- high positive skewness,

-- medians at or near zero, and

-- a lognormal distribution when zero-value data are excluded.

(6) High fuel population variability appears to be attributed to:

-- natural contagion and spatial heterogeneity of fuels within stands,

-- artificial contagion and bimodality within stands due to

-- low sample intensity,

-- short sample transects,

-- lack of sample design, and

-- sample error.

The stand means resulting from the apparent bimodal fuel distributions are therefore not very representative, or inadequately represent, the within-stand fuel condition. The means therefore have a high error term associated with them and are not very stable, as manifested by the non-normality of the stand mean fuel populations.

(7) All measured stand and site factors together account for less than 20 percent of the observed variance in fuels of pure Douglas-fir stands over 20 years of age.

-- correlation coefficients between fuels and stand and site factors never exceed 0.35,

-- correlation coefficients are seldom significant, even though the 5 percent significance level is associated with an r of only 0.174,

-- stand density and its squared term are the best covariates with dead and down fuel loads, accounting for 12.6 percent of the total fuel load variance,

-- basal area and its natural logarithm transformation are the best co-variates with duff layer thickness, accounting for 12.4 percent of the variance,

-- site productivity is the second best covariate, controlling 3.4 percent of the variance in total fuel load and 2.0 percent of duff thickness variance,

-- stand age accounts for less than 2 percent of the variance in total fuel load and duff thickness not explained by stand density and site productivity.

(8) Poor correlations between stand fuel means and associated stand and site factors is most probably due to:

-- high natural variability of forest fuels,

-- heterogeneity of fuels and stand factors within stands,

-- stand and site factors that are, like fuels, sample estimates with their own associated within-stand variance and sample error.

-- underlying causal relationships between forest fuels and stand and site factors that are complex, most likely nonlinear, and confounded by any number of known and unknown factors,

-- forest fuels conditions that are probably more directly related to the rates at which stand conditions change rather than their state as estimated at the time of inventory, and

-- lack of information on individual stand history that may have affected its fuel condition, such as

  -- the cause of the preceeding stand's decline,

  -- the conditions affecting establishment of the current stand, and

  -- the occurrence and pattern of any light ground fires within the stand that are undetectable during inventory.

3.7. Recommendations for Douglas-fir Natural Fuels Modeling

(1) An empirical approach to modeling natural fuels conditions of interior Douglas-fir stands should not be based upon a regression or covariate analysis. Stand mean fuel populations have non-normal distributions with few significant correlations between fuels and stand and site factors. Less than 20 percent of the fuel population variance can be controlled by all usual stand and site measures, e.g. stand age, stand density, stand d.b.h., stand basal area, terrain slope, elevation, aspect, site index, and site productivity. This may not, however, necessarily be true for other cover types. Alexander[5/] accounted for 45 to 65 percent of the variation in lodgepole pine dead and down fuels, but his regression equations used some unusual independent variables such as dead stem volume, live stem volume, and dead stem density.

(2) Stand age may not be an important consideration in modeling natural fuels under Douglas-fir overstories. It is less important than stand density or site productivity in controlling fuel sample variance, accounting for less than 5 percent of the variation in all 6 fuel categories. Age appears to be a poor substitute for more causal factors such as stand density, d.b.h., or basal area. Furthermore, changes in natural fuels in unmanaged stands over time is probably of little or no consequence compared to the effects of management activities and their timing on stand fuels. Again, this recommendation is for interior Douglas-fir only, and may not apply to other overstory species. Alexander[5/] found stand age correlations with lodgepole pine dead and down fuel loads to range from 0.07 to 0.70.

(3) An alternative approach to empirical fuel modeling of undisturbed Douglas-fir stands could involve the construction of simple cumulative fre-

quency distributions (cfd's) of stand mean or plot-by-plot fuel data. Cfd's may be compiled from various stratifications of the data and compared for significant differences with respect to forest management practices. This approach will be taken in the following section to construct Douglas-fir natural fuels models.

(4) A second alternative could be fuel models based upon known silvicultural relationships among site index, site productivity, habitat type, stand density, stem d.b.h., basal area, growth rate, pruning habit, mortality, and their rates of change. Such stand prognosis models are available or under development for northern coniferous forests (Stage 1973), and could be combined with available crown fuels relationships (Brown 1978) and debris prediction models (Brown et.al. 1977) to predict natural fuels accumulation in a process-oriented model.

4. DOUGLAS-FIR NATURAL FUELS MODELS

4.1. Methods

Empirical models of natural fuels under Douglas-fir canopies were constructed from the Northern Region's stand mean fuel inventory database. The models simply consist of cumulative frequency distributions (cfd's) for the 6 fuel characteristics within 4 canopy types. The use of cfd's as fuel models was used in lieu of a regression or covariate analysis approach as recommended in the previous section, and has been used elsewhere[6/]. The 6 fuel characteristics modeled are:

-- 10-hour dead and down fuel load,

-- 100-hour dead and down fuel load,

-- 1000-hour sound dead and down fuel load,

-- 1000-hour rotten dead and down fuel load,

-- 'total' dead and down fuel load (excluding 1-hour fuels), and

-- duff layer thickness.

Cumulative frequency distributions were derived for each of the 6 fuel types within 4 overstory canopy groups:

-- pure Douglas-fir stands,

-- mixed Douglas-fir stands,

-- pooled (pure and mixed) Douglas-fir stands, and

-- other forested stands without Douglas-fir.

The pure and mixed Douglas-fir fuels were compared for significant differences as were the pooled Douglas-fir and other forested stand fuels. Significance criteria were based upon minimum Rothermel (1972) fire model fuel load input resolution as determined by a sensitivity analysis[7/]. If mean differences between the fuel cfd's (or sections of the cfd's) did not exceed the fire

model's input resolution, they were considered insignificant with respect to forest management practices.

4.2. Significance Criteria

A sensitivity analysis of the Rothermel (1972) fire model was performed by Bevins[7/] to determine its minimum fuel load input resolution. These minimum fuel load values were used as significance criteria in determining whether cfd's from 2 populations were the same or different.

The senitivity analysis used baseline (initial) fuel loads, fuel moistures, wind speed, and slope (table 11) to derive a baseline rate of spread, 9.1-feet per minute, and flame length, 2.1-feet. The baseline fuel loads correspond to the 98th percentile fine fuel load and 82nd percentile large fuel load of the pooled Douglas-fir stand data. Fuel load inputs were then incremented until the baseline fireline intensity and rate of spread changed by ± 10 percent, e.g., a 0.91-feet per second change in rate of spread and a 0.13-feet change in flame length. The resulting minimum fuel load resolutions and significance levels are:

Fuel type	Minimum resolution (Significance level)
10-hour	4.2-tons per acre
100-hour	9.0-tons per acre
1000-hour	9.9-tons per acre

The mean differences between cfd's were computed over 7 percentile ranges:

-- 1st to 25th percentile,

-- 26th to 50th percentile,

-- 51st to 75th percentile,

-- 76th to 90th percentile,

Table 11 : Fire model senitivity analysis baseline inputs

	1-hour	10-hour	100-hour	1000-hour
Fuel load (t/ac)	3.40	4.50	4.50	22.50
Fuel moisture (%)	3.00	5.00	13.00	16.00
10% resolution load	2.45	4.15	9.00	9.90

windspeed = 2.0 mph, midflame height

slope = 10 degrees (16.6%)

Fire model outputs for sensitivity analysis baseline inputs

Fire behavior characteristics	Value
Rate of spread (feet per minute)	9.12
Fireline intensity (kcal/m-s)	42.05
Flame length (feet)	2.10

-- 91st to 95th percentile,

-- 96th to 100th percentile, and

-- 1st to 100th percentile.

4.3. Results

The cumulative frequency distribution curves of 6 fuel characteristics under 4 overstory types are presented in appendix A (tables 14 - 16). The mean differences between pure and mixed Douglas-fir stands and between Douglas-fir and other forested stands are presented in tables 12 and 13, respectively.

4.3.1. Pure vs. Mixed Douglas-fir Stand Mean Fuel Populations

No significant differences are evident between the pure and mixed Douglas-fir 10-hour loads, 100-hour loads, and duff depths throughout any portion of their cfd's. The only significant difference between the 2 canopy types' 1000-hour loads occurs in the 96th to 100th percentile interval. This difference is due solely to differences in the maximum values of the sound and rotten fuel loads between the 2 types. Pure and mixed Douglas-fir stand fuels were therefore determined to be from the same population.

4.3.2. Douglas-fir vs. Other Species Stand Mean Fuel Populations

The pooled Douglas-fir fuels cfd's were then compared to those from other forested cover types (table 13). Again, no significant differences were found in the 10-hour loads, 100-hour loads, and duff depths. Significant differences do emerge, however, at the 1000-hour fuel load 90th percentile level.

Table 12: PURE DOUGLAS-FIR STANDS VS. MIXED DOUGLAS-FIR STANDS

CUMULATIVE FREQUENCY DISTRIBUTION MEAN DIFFERENCES

PERCENTILE RANGE	10-HR	100-HR	1000-HR SOUND	1000-HR ROTTEN	TOTAL LOAD	DUFF DEPTH
1 - 25	.03	.05	0.	.01	.35	.08
26 - 50	.04	.21	.23	.40	1.30	.06
51 - 75	.03	.19	.58	1.20	1.69	.02
76 - 90	.06	.12	1.98	.55	1.35	.05
91 - 95	.10	.20	.90	2.04	4.27	.05
96 - 100	1.54	2.29	6.99	6.36	6.09	.23
1 - 100	.12	.25	.89	.91	1.56	.06

Table 13: DOUGLAS-FIR VS. OTHER OVERSTORY SPECIES

CUMULATIVE FREQUENCY DISTRIBUTION MEAN DIFFERENCES

PERCENTILE RANGE	10-HR	100-HR	1000-HR SOUND	1000-HR ROTTEN	TOTAL LOAD	DUFF DEPTH
1 - 25	.05	.03	.01	.03	.70	.02
26 - 50	.05	.12	1.03	.52	2.44	.06
51 - 75	.04	.19	3.06	1.48	5.36	.26
76 - 90	.10	.40	7.14	3.32	9.37	.53
91 - 95	.13	.32	11.37	3.32	12.07	.67
96 - 100	.74	.45	47.90	26.51	48.46	1.30
1 - 100	.09	.18	5.06	2.50	6.56	.26

4.4. Discussion

Fuel cumulative frequency distributions provide an acceptable alternative to regression or covariate analysis methods of Douglas-fir natural fuels modeling.

-- The cfd's preserve the observed variability in the sample data and require no assumptions about the underlying distribution of fuel populations.

-- While the cfd's are unable to 'predict' fuels conditions within a specific stand, regression techniques were also found to be wanting in this respect. Stand and site factors could not account for more than 15 to 20 percent of the variance in fuel populations, leaving an unacceptable amount of unexplained variation.

-- Fuel cfd's may be compared between populations or subpopulations and tested for significant differences, either statistically or with respect to forest management practices. For example, section 3 of this report found stand age to be a poor predictor of fuel values, and stand density and site productivity were only slightly better. If 'dynamic' fuel modeling is still a viable management tool, then cfd's may be constructed and tested between stand age classes within specific stand density and site productivity classes.

-- The cfd's may be randomly sampled by stochastic fuel models.

-- With a minimum amount of information about local Douglas-fir stands and their condition, a fuels or land manager can select fuel cfd percentile (or quartile) levels that best represent the stands. The fuel values at the selected percentile levels will then constitute a fuel model.

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5.2. Footnotes

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APPENDIX A : DOUGLAS-FIR FUELS CUMULATIVE FREQUENCY DISTRIBUTIONS

Table 14a : Pure Douglas-fir 10-hour fuel load cumulative frequency distribution

10-HOUR FUEL LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	.03	26	.65	51	1.00	76	1.30
2	.16	27	.70	52	1.00	77	1.40
3	.20	28	.70	53	1.00	78	1.40
4	.20	29	.70	54	1.00	79	1.40
5	.20	30	.70	55	1.10	80	1.42
6	.27	31	.70	56	1.10	81	1.50
7	.30	32	.70	57	1.10	82	1.50
8	.30	33	.76	58	1.10	83	1.50
9	.36	34	.80	59	1.10	84	1.54
10	.40	35	.80	60	1.10	85	1.73
11	.40	36	.80	61	1.10	86	1.80
12	.40	37	.80	62	1.10	87	1.80
13	.40	38	.90	63	1.10	88	1.80
14	.41	39	.90	64	1.10	89	1.80
15	.50	40	.90	65	1.10	90	1.90
16	.50	41	.90	66	1.11	91	1.90
17	.50	42	.90	67	1.20	92	1.90
18	.50	43	.90	68	1.20	93	2.00
19	.50	44	.90	69	1.20	94	2.13
20	.50	45	.90	70	1.20	95	2.37
21	.50	46	.93	71	1.20	96	2.50
22	.54	47	1.00	72	1.20	97	2.55
23	.60	48	1.00	73	1.22	98	2.90
24	.60	49	1.00	74	1.30	99	3.11
25	.60	50	1.00	75	1.30	100	3.30

COMPILED FROM 129 STAND MEANS.

Table 14b : Pure Douglas-fir 100-hour fuel load cumulative frequency distribution

100-HOUR FUEL LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.70	51	1.20	76	2.20
2	0.	27	.70	52	1.30	77	2.23
3	0.	28	.70	53	1.30	78	2.30
4	0.	29	.70	54	1.37	79	2.39
5	0.	30	.70	55	1.40	80	2.40
6	.07	31	.70	56	1.42	81	2.45
7	.10	32	.70	57	1.50	82	2.50
8	.23	33	.70	58	1.50	83	2.50
9	.30	34	.79	59	1.50	84	2.50
10	.30	35	.80	60	1.54	85	2.50
11	.30	36	.80	61	1.60	86	2.69
12	.30	37	.80	62	1.70	87	2.70
13	.30	38	.90	63	1.70	88	2.70
14	.30	39	.90	64	1.76	89	2.78
15	.34	40	.90	65	1.80	90	2.80
16	.40	41	.90	66	1.81	91	2.84
17	.40	42	.92	67	1.90	92	2.90
18	.40	43	1.00	68	1.90	93	2.90
19	.45	44	1.00	69	1.90	94	3.03
20	.50	45	1.10	70	2.00	95	3.62
21	.60	46	1.10	71	2.00	96	3.97
22	.60	47	1.10	72	2.00	97	4.51
23	.60	48	1.19	73	2.10	98	5.82
24	.60	49	1.20	74	2.10	99	8.14
25	.63	50	1.20	75	2.10	100	11.20

COMPILED FROM 129 STAND MEANS.

Table 14c : Pure Douglas-fir 1000-hour sound fuel load cumulative frequency distribution

1000-HOUR SOUND LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.65	51	2.50	76	5.61
2	0.	27	.70	52	2.51	77	5.80
3	0.	28	.70	53	2.67	78	5.86
4	0.	29	.70	54	2.80	79	5.90
5	0.	30	.70	55	2.90	80	6.02
6	0.	31	.80	56	2.95	81	6.20
7	0.	32	.90	57	3.10	82	6.38
8	0.	33	.90	58	3.18	83	6.41
9	0.	34	.99	59	3.23	84	6.54
10	0.	35	1.02	60	3.58	85	6.67
11	0.	36	1.10	61	3.70	86	6.98
12	.05	37	1.17	62	3.70	87	7.32
13	.10	38	1.20	63	3.91	88	7.91
14	.11	39	1.30	64	4.26	89	8.18
15	.20	40	1.30	65	4.30	90	8.60
16	.20	41	1.39	66	4.40	91	8.68
17	.29	42	1.50	67	4.44	92	9.28
18	.30	43	1.55	68	4.50	93	10.96
19	.30	44	1.75	69	4.70	94	11.31
20	.30	45	1.90	70	4.70	95	12.51
21	.31	46	1.90	71	4.76	96	13.08
22	.40	47	2.09	72	4.89	97	14.30
23	.47	48	2.29	73	5.23	98	18.96
24	.50	49	2.32	74	5.45	99	23.81
25	.53	50	2.45	75	5.58	100	28.60

COMPILED FROM 129 STAND MEANS.

Table 14d : Pure Douglas-fir 1000-hour rotten fuel load cumulative frequency distribution

1000-HR ROTTEN LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	1.80	51	4.90	76	10.50
2	0.	27	1.88	52	5.00	77	10.80
3	0.	28	2.00	53	5.04	78	11.26
4	0.	29	2.04	54	5.10	79	11.48
5	0.	30	2.17	55	5.10	80	11.80
6	0.	31	2.20	56	5.22	81	11.80
7	.10	32	2.23	57	5.30	82	11.88
8	.13	33	2.36	58	5.71	83	12.42
9	.20	34	2.74	59	6.13	84	12.92
10	.29	35	2.92	60	6.40	85	13.43
11	.54	36	3.00	61	6.47	86	13.69
12	.75	37	3.00	62	6.50	87	13.72
13	.80	38	3.10	63	6.85	88	14.01
14	.91	39	3.20	64	7.11	89	14.44
15	1.00	40	3.26	65	7.46	90	15.02
16	1.06	41	3.30	66	7.61	91	15.32
17	1.19	42	3.42	67	7.74	92	16.79
18	1.20	43	3.50	68	7.80	93	17.59
19	1.30	44	3.58	69	8.00	94	18.49
20	1.48	45	3.70	70	8.32	95	21.53
21	1.50	46	3.87	71	8.60	96	23.18
22	1.54	47	4.26	72	8.95	97	30.91
23	1.67	48	4.30	73	9.15	98	31.04
24	1.70	49	4.40	74	9.63	99	39.76
25	1.80	50	4.65	75	10.20	100	56.10

COMPILED FROM 129 STAND MEANS.

Table 14e : Pure Douglas-fir total fuel load cumulative frequency distribution

TOTAL DEAD+DOWN LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	.23	26	6.91	51	11.32	76	19.41
2	.42	27	7.08	52	11.51	77	19.70
3	1.02	28	7.11	53	11.64	78	19.82
4	1.22	29	7.20	54	11.83	79	19.90
5	1.48	30	7.27	55	11.90	80	20.22
6	1.77	31	7.40	56	12.10	81	20.35
7	1.91	32	7.43	57	12.15	82	20.48
8	2.20	33	7.90	58	12.36	83	20.71
9	2.46	34	8.37	59	12.52	84	21.41
10	2.59	35	8.40	60	12.74	85	22.76
11	3.24	36	8.44	61	13.15	86	23.18
12	3.50	37	8.50	62	13.40	87	23.30
13	3.60	38	8.60	63	13.50	88	23.72
14	3.71	39	8.83	64	13.50	89	24.51
15	3.87	40	9.02	65	13.67	90	25.47
16	4.06	41	9.10	66	14.64	91	27.31
17	4.66	42	9.12	67	14.99	92	27.94
18	4.92	43	9.39	68	15.82	93	29.26
19	5.00	44	9.75	69	16.10	94	31.73
20	5.08	45	9.91	70	16.55	95	32.02
21	5.48	46	10.14	71	17.08	96	38.08
22	6.41	47	10.46	72	17.29	97	42.12
23	6.60	48	10.59	73	17.60	98	47.61
24	6.60	49	10.76	74	17.97	99	52.22
25	6.73	50	11.00	75	18.78	100	63.20

COMPILED FROM 129 STAND MEANS.

Table 14f : Pure Douglas-fir duff layer thickness cumulative frequency distribution

DUFF LAYER DEPTH CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.50	51	1.00	76	1.40
2	.06	27	.58	52	1.00	77	1.40
3	.10	28	.60	53	1.00	78	1.40
4	.10	29	.60	54	1.00	79	1.40
5	.15	30	.60	55	1.00	80	1.50
6	.20	31	.60	56	1.00	81	1.50
7	.20	32	.63	57	1.05	82	1.50
8	.20	33	.70	58	1.10	83	1.51
9	.20	34	.70	59	1.10	84	1.60
10	.20	35	.72	60	1.10	85	1.60
11	.22	36	.80	61	1.10	86	1.60
12	.30	37	.80	62	1.10	87	1.70
13	.30	38	.80	63	1.13	88	1.75
14	.30	39	.80	64	1.20	89	1.80
15	.30	40	.80	65	1.20	90	1.80
16	.36	41	.80	66	1.20	91	1.80
17	.40	42	.90	67	1.24	92	1.87
18	.40	43	.90	68	1.30	93	2.00
19	.40	44	.90	69	1.30	94	2.00
20	.40	45	.90	70	1.30	95	2.06
21	.50	46	.90	71	1.30	96	2.18
22	.50	47	.90	72	1.30	97	2.33
23	.50	48	.90	73	1.40	98	2.54
24	.50	49	.90	74	1.40	99	3.24
25	.50	50	.95	75	1.40	100	3.50

COMPILED FROM 129 STAND MEANS.

Table 15a : Mixed Douglas-fir 10-hour fuel load cumulative frequency distribution

10-HOUR FUEL LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.60	51	.90	76	1.50
2	0.	27	.60	52	.90	77	1.50
3	0.	28	.60	53	1.00	78	1.50
4	.10	29	.60	54	1.00	79	1.50
5	.10	30	.60	55	1.00	80	1.60
6	.10	31	.60	56	1.00	81	1.60
7	.10	32	.60	57	1.10	82	1.60
8	.20	33	.60	58	1.10	83	1.70
9	.20	34	.67	59	1.10	84	1.70
10	.20	35	.70	60	1.10	85	1.77
11	.30	36	.70	61	1.10	86	1.90
12	.30	37	.70	62	1.10	87	2.00
13	.30	38	.70	63	1.20	88	2.10
14	.30	39	.80	64	1.20	89	2.10
15	.30	40	.80	65	1.20	90	2.20
16	.40	41	.80	66	1.20	91	2.20
17	.40	42	.80	67	1.28	92	2.21
18	.40	43	.80	68	1.30	93	2.40
19	.40	44	.80	69	1.30	94	2.41
20	.50	45	.80	70	1.30	95	2.90
21	.50	46	.80	71	1.30	96	3.20
22	.50	47	.90	72	1.40	97	3.40
23	.50	48	.90	73	1.40	98	3.91
24	.50	49	.90	74	1.40	99	5.72
25	.53	50	.90	75	1.40	100	12.90

COMPILED FROM 349 STAND MEANS.

Table 15b : Mixed Douglas-fir 100-hour fuel load cumulative frequency distribution

100-HOUR FUEL LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.40	51	1.40	76	2.30
2	0.	27	.50	52	1.50	77	2.37
3	0.	28	.50	53	1.50	78	2.50
4	0.	29	.60	54	1.50	79	2.60
5	0.	30	.60	55	1.50	80	2.70
6	0.	31	.60	56	1.60	81	2.70
7	0.	32	.67	57	1.60	82	2.80
8	0.	33	.70	58	1.60	83	2.80
9	0.	34	.70	59	1.60	84	2.82
10	0.	35	.72	60	1.70	85	3.00
11	0.	36	.80	61	1.70	86	3.10
12	0.	37	.90	62	1.70	87	3.20
13	0.	38	.90	63	1.80	88	3.30
14	0.	39	1.00	64	1.84	89	3.56
15	0.	40	1.10	65	1.90	90	3.70
16	0.	41	1.10	66	1.90	91	3.86
17	0.	42	1.10	67	2.00	92	4.31
18	0.	43	1.10	68	2.03	93	4.40
19	0.	44	1.10	69	2.10	94	4.91
20	0.	45	1.10	70	2.20	95	5.26
21	.13	46	1.20	71	2.20	96	5.60
22	.28	47	1.20	72	2.20	97	6.45
23	.30	48	1.30	73	2.20	98	7.31
24	.38	49	1.30	74	2.20	99	8.60
25	.40	50	1.30	75	2.20	100	16.40

COMPILED FROM 349 STAND MEANS.

Table 15c : Mixed Douglas-fir 1000-hour sound fuel load cumulative frequency distribution

1000-HOUR SOUND LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	0.	51	1.60	76	5.70
2	0.	27	0.	52	1.85	77	5.95
3	0.	28	0.	53	1.90	78	6.30
4	0.	29	0.	54	2.10	79	7.07
5	0.	30	0.	55	2.30	80	7.34
6	0.	31	0.	56	2.44	81	7.74
7	0.	32	0.	57	2.59	82	8.42
8	0.	33	0.	58	2.70	83	9.43
9	0.	34	.17	59	2.80	84	9.75
10	0.	35	.20	60	2.84	85	10.20
11	0.	36	.30	61	3.00	86	10.61
12	0.	37	.31	62	3.10	87	11.09
13	0.	38	.46	63	3.20	88	11.84
14	0.	39	.50	64	3.50	89	12.62
15	0.	40	.60	65	3.59	90	13.01
16	0.	41	.60	66	3.70	91	14.46
17	0.	42	.66	67	3.98	92	14.83
18	0.	43	.71	68	4.13	93	16.31
19	0.	44	.80	69	4.20	94	16.66
20	0.	45	.90	70	4.30	95	19.17
21	0.	46	.95	71	4.48	96	23.01
22	0.	47	1.20	72	4.60	97	30.21
23	0.	48	1.40	73	4.90	98	31.34
24	0.	49	1.40	74	5.13	99	38.37
25	0.	50	1.55	75	5.35	100	79.90

COMPILED FROM 349 STAND MEANS.

Table 15d : Mixed Douglas-fir 1000-hour rotten fuel load cumulative frequency distribution

1000-HR ROTTEN LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.60	51	4.40	76	11.72
2	0.	27	.70	52	4.70	77	11.90
3	0.	28	.80	53	4.90	78	12.22
4	0.	29	.82	54	5.35	79	12.67
5	0.	30	1.10	55	5.50	80	12.72
6	0.	31	1.10	56	5.74	81	13.20
7	0.	32	1.20	57	6.09	82	13.52
8	0.	33	1.50	58	6.24	83	13.87
9	0.	34	1.70	59	6.49	84	14.55
10	0.	35	1.80	60	6.70	85	15.20
11	0.	36	1.96	61	6.89	86	15.51
12	0.	37	2.11	62	7.45	87	16.33
13	0.	38	2.30	63	7.90	88	16.66
14	0.	39	2.41	64	8.00	89	17.60
15	0.	40	2.66	65	8.10	90	18.41
16	0.	41	2.90	66	8.40	91	19.18
17	0.	42	2.96	67	8.50	92	20.62
18	0.	43	3.01	68	8.83	93	21.46
19	0.	44	3.16	69	9.00	94	24.95
20	0.	45	3.31	70	9.26	95	26.52
21	0.	46	3.60	71	9.78	96	28.18
22	0.	47	3.80	72	10.23	97	30.90
23	.10	48	3.95	73	10.55	98	33.06
24	.28	49	4.00	74	11.13	99	41.97
25	.53	50	4.10	75	11.38	100	94.80

COMPILED FROM 349 STAND MEANS.

Table 15e : Mixed Douglas-fir total fuel load cumulative frequency distribution

TOTAL DEAD+DOWN LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	.30	26	5.50	51	12.20	76	20.97
2	.40	27	5.72	52	12.44	77	21.45
3	.50	28	5.90	53	12.80	78	22.02
4	.60	29	6.00	54	12.95	79	22.63
5	.75	30	6.20	55	13.60	80	23.42
6	.89	31	6.40	56	14.04	81	24.37
7	1.10	32	6.64	57	14.39	82	25.00
8	1.20	33	7.00	58	14.44	83	25.50
9	1.24	34	7.30	59	14.99	84	26.13
10	1.59	35	7.62	60	15.24	85	27.43
11	1.74	36	8.03	61	15.49	86	28.21
12	1.99	37	8.21	62	15.78	87	29.70
13	2.30	38	8.56	63	16.19	88	30.51
14	2.49	39	8.71	64	16.20	89	30.94
15	2.60	40	8.96	65	16.40	90	32.43
16	2.70	41	9.51	66	16.70	91	33.10
17	2.90	42	9.66	67	17.08	92	34.83
18	3.48	43	9.91	68	17.50	93	36.61
19	3.70	44	10.20	69	17.84	94	37.95
20	3.88	45	10.41	70	18.43	95	40.21
21	4.00	46	10.65	71	18.88	96	43.01
22	4.53	47	11.31	72	19.23	97	48.26
23	4.90	48	11.60	73	19.83	98	55.74
24	5.18	49	11.80	74	20.13	99	65.72
25	5.40	50	11.90	75	20.65	100	108.30

COMPILED FROM 349 STAND MEANS.

Table 15f : Mixed Douglas-fir duff layer thickness cumulative frequency distribution

DUFF LAYER DEPTH CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.30	51	.90	76	1.40
2	0.	27	.30	52	.90	77	1.40
3	0.	28	.30	53	.90	78	1.50
4	0.	29	.40	54	.90	79	1.50
5	0.	30	.40	55	.90	80	1.50
6	0.	31	.40	56	.94	81	1.50
7	0.	32	.40	57	1.00	82	1.60
8	0.	33	.50	58	1.00	83	1.60
9	0.	34	.50	59	1.00	84	1.60
10	0.	35	.60	60	1.00	85	1.70
11	.10	36	.60	61	1.00	86	1.80
12	.10	37	.60	62	1.10	87	1.80
13	.10	38	.60	63	1.10	88	2.00
14	.10	39	.70	64	1.10	89	2.00
15	.10	40	.70	65	1.10	90	2.01
16	.10	41	.70	66	1.10	91	2.10
17	.10	42	.70	67	1.10	92	2.20
18	.20	43	.70	68	1.20	93	2.30
19	.20	44	.70	69	1.20	94	2.40
20	.20	45	.71	70	1.20	95	2.50
21	.20	46	.80	71	1.30	96	2.70
22	.20	47	.80	72	1.30	97	2.95
23	.20	48	.80	73	1.30	98	3.10
24	.20	49	.80	74	1.30	99	3.56
25	.30	50	.90	75	1.38	100	6.30

COMPILED FROM 349 STAND MEANS.

Table 16a : Pooled Douglas-fir 10-hour fuel load cumulative frequency distribution

10-HOUR FUEL LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.50	51	1.00	76	1.50
2	0.	27	.60	52	1.00	77	1.50
3	0.	28	.60	53	1.00	78	1.50
4	0.	29	.60	54	1.00	79	1.50
5	.10	30	.60	55	1.10	80	1.60
6	.10	31	.60	56	1.10	81	1.60
7	.10	32	.60	57	1.10	82	1.70
8	.20	33	.70	58	1.10	83	1.70
9	.20	34	.70	59	1.10	84	1.80
10	.30	35	.70	60	1.10	85	1.80
11	.30	36	.70	61	1.10	86	1.90
12	.30	37	.70	62	1.20	87	1.90
13	.30	38	.80	63	1.20	88	2.00
14	.30	39	.80	64	1.20	89	2.10
15	.38	40	.80	65	1.20	90	2.18
16	.40	41	.80	66	1.20	91	2.20
17	.40	42	.80	67	1.20	92	2.30
18	.40	43	.80	68	1.30	93	2.40
19	.40	44	.90	69	1.30	94	2.50
20	.50	45	.90	70	1.30	95	2.84
21	.50	46	.90	71	1.30	96	3.00
22	.50	47	.90	72	1.40	97	3.40
23	.50	48	.90	73	1.40	98	3.58
24	.50	49	.90	74	1.40	99	4.58
25	.50	50	1.00	75	1.40	100	12.90

COMPILED FROM 712 STAND MEANS.

Table 16b : Pooled Douglas-fir 100-hour fuel load cumulative frequency distribution

100-HOUR FUEL LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.40	51	1.21	76	2.30
2	0.	27	.40	52	1.30	77	2.32
3	0.	28	.50	53	1.30	78	2.50
4	0.	29	.50	54	1.40	79	2.55
5	0.	30	.60	55	1.46	80	2.70
6	0.	31	.60	56	1.50	81	2.70
7	0.	32	.68	57	1.50	82	2.80
8	0.	33	.70	58	1.50	83	2.80
9	0.	34	.70	59	1.60	84	2.90
10	0.	35	.70	60	1.60	85	3.00
11	0.	36	.70	61	1.63	86	3.13
12	0.	37	.70	62	1.70	87	3.20
13	0.	38	.80	63	1.70	88	3.40
14	0.	39	.87	64	1.80	89	3.67
15	0.	40	.90	65	1.90	90	4.00
16	0.	41	.90	66	1.90	91	4.30
17	0.	42	1.00	67	2.00	92	4.40
18	0.	43	1.10	68	2.10	93	4.40
19	0.	44	1.10	69	2.10	94	4.83
20	0.	45	1.10	70	2.14	95	5.40
21	0.	46	1.10	71	2.20	96	6.05
22	0.	47	1.10	72	2.20	97	6.66
23	.28	48	1.10	73	2.20	98	8.06
24	.30	49	1.10	74	2.20	99	10.62
25	.40	50	1.20	75	2.20	100	23.20

COMPILED FROM 712 STAND MEANS.

Table 16c : Pooled Douglas-fir 1000-hour sound fuel load cumulative frequency distribution

1000-HOUR SOUND LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	0.	51	1.50	76	5.60
2	0.	27	0.	52	1.60	77	5.72
3	0.	28	0.	53	1.74	78	6.04
4	0.	29	0.	54	1.90	79	6.30
5	0.	30	0.	55	2.10	80	6.60
6	0.	31	0.	56	2.20	81	7.00
7	0.	32	0.	57	2.40	82	7.47
8	0.	33	0.	58	2.50	83	8.09
9	0.	34	.10	59	2.70	84	8.60
10	0.	35	.20	60	2.80	85	9.32
11	0.	36	.30	61	2.90	86	9.73
12	0.	37	.30	62	3.04	87	10.43
13	0.	38	.40	63	3.10	88	11.16
14	0.	39	.50	64	3.20	89	12.17
15	0.	40	.50	65	3.38	90	13.00
16	0.	41	.60	66	3.50	91	14.38
17	0.	42	.60	67	3.70	92	14.80
18	0.	43	.70	68	4.10	93	16.23
19	0.	44	.80	69	4.23	94	17.60
20	0.	45	.90	70	4.34	95	19.12
21	0.	46	.95	71	4.50	96	22.20
22	0.	47	1.10	72	4.60	97	29.31
23	0.	48	1.28	73	4.78	98	33.02
24	0.	49	1.40	74	5.00	99	44.44
25	0.	50	1.50	75	5.20	100	79.90

COMPILED FROM 712 STAND MEANS.

Table 16d : Pooled Douglas-fir 1000-hour rotten fuel load cumulative frequency distribution

1000-HR ROTTEN LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.71	51	4.21	76	11.50
2	0.	27	.80	52	4.42	77	11.80
3	0.	28	1.00	53	4.80	78	12.10
4	0.	29	1.10	54	4.90	79	12.60
5	0.	30	1.20	55	5.10	80	12.70
6	0.	31	1.20	56	5.30	81	13.07
7	0.	32	1.40	57	5.48	82	13.50
8	0.	33	1.50	58	5.80	83	13.70
9	0.	34	1.70	59	6.10	84	14.41
10	0.	35	1.80	60	6.40	85	15.12
11	0.	36	2.00	61	6.50	86	15.43
12	0.	37	2.10	62	6.70	87	16.09
13	0.	38	2.20	63	6.96	88	17.01
14	0.	39	2.30	64	7.50	89	17.60
15	0.	40	2.40	65	7.70	90	18.50
16	0.	41	2.59	66	7.90	91	19.60
17	0.	42	2.90	67	8.20	92	21.11
18	0.	43	3.00	68	8.50	93	24.18
19	0.	44	3.13	69	8.80	94	26.16
20	0.	45	3.30	70	9.00	95	27.92
21	0.	46	3.30	71	9.10	96	30.95
22	.10	47	3.50	72	9.56	97	33.26
23	.30	48	3.70	73	9.98	98	40.74
24	.49	49	3.90	74	10.49	99	43.56
25	.60	50	4.00	75	11.10	100	94.80

COMPILED FROM 712 STAND MEANS.

Table 16e : Pooled Douglas-fir total fuel load cumulative frequency distribution

TOTAL DEAD+DOWN LOAD CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	.30	26	5.40	51	11.90	76	20.52
2	.32	27	5.52	52	11.92	77	20.95
3	.50	28	5.84	53	12.20	78	21.50
4	.65	29	6.00	54	12.45	79	22.25
5	.96	30	6.26	55	12.80	80	23.26
6	1.10	31	6.40	56	13.07	81	24.00
7	1.20	32	6.60	57	13.50	82	24.48
8	1.40	33	6.80	58	13.60	83	25.10
9	1.60	34	7.10	59	14.21	84	26.12
10	1.72	35	7.30	60	14.52	85	27.34
11	1.90	36	7.50	61	14.93	86	28.00
12	2.14	37	7.74	62	15.30	87	29.49
13	2.40	38	8.16	63	15.56	88	30.56
14	2.57	39	8.40	64	16.07	89	31.70
15	2.70	40	8.58	65	16.20	90	32.54
16	2.90	41	8.80	66	16.40	91	33.58
17	3.30	42	9.10	67	16.90	92	37.00
18	3.42	43	9.52	68	17.22	93	39.26
19	3.70	44	9.80	69	17.60	94	42.06
20	3.90	45	9.90	70	18.04	95	45.42
21	4.10	46	10.20	71	18.60	96	49.10
22	4.50	47	10.60	72	19.06	97	51.49
23	4.90	48	10.98	73	19.38	98	55.32
24	5.09	49	11.39	74	19.90	99	66.61
25	5.30	50	11.60	75	20.20	100	108.30

COMPILED FROM 712 STAND MEANS.

Table 16f : Pooled Douglas-fir duff layer thickness cumulative frequency distribution

DUFF LAYER DEPTH CUMULATIVE DISTRIBUTION FREQUENCY

PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE	PRCNTL	VALUE
1	0.	26	.40	51	.90	76	1.40
2	0.	27	.50	52	.90	77	1.42
3	0.	28	.50	53	.90	78	1.50
4	0.	29	.50	54	1.00	79	1.50
5	0.	30	.50	55	1.00	80	1.50
6	.10	31	.60	56	1.00	81	1.50
7	.10	32	.60	57	1.00	82	1.60
8	.10	33	.60	58	1.00	83	1.60
9	.10	34	.60	59	1.00	84	1.70
10	.10	35	.60	60	1.10	85	1.72
11	.10	36	.60	61	1.10	86	1.80
12	.20	37	.70	62	1.10	87	1.80
13	.20	38	.70	63	1.10	88	1.90
14	.20	39	.70	64	1.10	89	2.00
15	.20	40	.70	65	1.20	90	2.00
16	.20	41	.70	66	1.20	91	2.10
17	.20	42	.70	67	1.20	92	2.20
18	.30	43	.80	68	1.20	93	2.30
19	.30	44	.80	69	1.30	94	2.43
20	.30	45	.80	70	1.30	95	2.60
21	.30	46	.80	71	1.30	96	2.80
22	.30	47	.80	72	1.30	97	2.96
23	.40	48	.88	73	1.30	98	3.28
24	.40	49	.90	74	1.40	99	3.80
25	.40	50	.90	75	1.40	100	6.60

COMPILED FROM 712 STAND MEANS.

APPENDIX B : NATURAL FUELS BY PREDOMINANT OVERSTORY SPECIES

Table 17a : 10-hour fuels by dominant overstory species

VARIABLE TEN
BY TYPE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	13	234.3722	18.0286	21.1581	.0000
WITHIN GROUPS	4187	3567.7016	.8521		
TOTAL	4200	3802.0738			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN		
DF	1116	[illegible]	[illegible]	.0309	0	13.5000	1.0313	TO	1.1525
DF-LP	86	.5116	.3969	.0428	0	1.9000	.5265	TO	.6967
PP	233	.7112	[illegible]	.0556	0	5.7000	.6017	TO	.8205
WWP	24	1.1083	.8973	.1832	0	3.5000	.7294	TO	1.4872
ES	122	1.2566	1.2450	.1127	0	9.4000	1.0334	TO	1.4797
ES-AF	475	1.1261	1.1219	.0515	0	14.1000	1.0250	TO	1.2273
WPC-WH	154	1.5792	1.0121	.0816	0	5.4000	1.4181	TO	1.7403
WH-AF	39	1.1821	.6934	.1111	0	3.0000	.9571	TO	1.4070
WL-GF-DF	504	1.3615	.9400	.0417	0	6.7000	1.2796	TO	1.4434
WL-PP-DF	36	1.2667	.6224	.1037	.3000	2.5000	1.0561	TO	1.4773
LPP	1015	[illegible]	.7545	.0236	0	4.5000	.8338	TO	.9274
WBP-LBP	236	.5860	.6706	.0437	0	4.3000	.6000	TO	.7720
HW-ASPEN	6	[illegible]	1.4404	.5882	.1000	3.7000	-.7120	TO	2.3120
NONCOMM	156	.5346	.6815	.0546	0	3.0000	.5258	TO	.7424
TOTAL	4201	1.0313			0	14.1000			
UNGROUPED DATA			.9514	.0147			1.0025	TO	1.0601
FIXED EFFECTS MODEL			.9231	.0142			1.0034	TO	1.0592
RANDOM EFFECTS MODEL			.3386	.1039			.8069	TO	1.2557

RANDOM EFFECTS MODEL - ESTIMATE OF BETWEEN COMPONENT VARIANCE .0637

Table 17b : 100-hour fuel load by dominant overstory species

VARIABLE HUNDRED
BY TYPE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	13	829.5649	63.8127	14.8802	.0000
WITHIN GROUPS	4187	17955.7128	4.2884		
TOTAL	4200	18785.2777			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN		
DF	1110	1.7449	2.1557	.0647	0	23.2000	1.6179	TO	1.8719
DF-LP	[illegible]	1.3145	1.4444	.1558	0	6.4000	1.0083	TO	1.6283
PP	233	1.0172	1.5400	.1009	0	9.7000	.8184	TO	1.2159
WWP	24	1.3417	.9537	.1947	0	4.3000	.9390	TO	1.7444
ES	122	2.2467	2.5728	.2329	0	15.1000	1.7856	TO	2.7079
ES-AF	475	1.7813	[illegible]	.0957	0	21.5000	1.5932	TO	1.9693
WRC-WH	154	3.1025	3.4747	.2800	0	20.3000	2.5494	TO	3.6558
WH-AF	39	1.3949	.9327	.1494	0	3.5000	1.0925	TO	1.6972
WL-GF-DF	509	2.3169	2.2103	.0980	0	16.4000	2.1244	TO	2.5094
WL-PP-DF	36	1.7972	1.2996	.2149	0	4.3000	1.3610	TO	2.2335
LPP	1015	1.7639	1.9912	.0625	0	20.4000	1.6412	TO	1.8865
WBP-LBP	236	1.0017	1.3351	.0870	0	9.6000	.8304	TO	1.1730
HW-ASPEN	6	1.2667	2.2079	.9014	0	5.4000	-1.0503	TO	3.5836
NONCOMM	156	1.0763	1.4047	.1125	0	6.5000	.8541	TO	1.2984
TOTAL	4201	1.7659			0	23.2000			
UNGROUPED DATA			2.1149	.0326			1.7018	TO	1.8297
FIXED EFFECTS MODEL			2.0709	.0320			1.7031	TO	1.8294
RANDOM EFFECTS MODEL			.7265	.1942			1.3463	TO	2.1852

RANDOM EFFECTS MODEL - ESTIMATE OF BETWEEN COMPONENT VARIANCE .2209

Table 17c : Sound 1000-hour fuel load by dominant overstory species

VARIABLE SOUND
K EXPR

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	13	47127.6969	3625.2075	25.1619	.0000
WITHIN GROUPS	4187	603242.4215	144.0751		
TOTAL	4200	650370.1184			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN
DF	1110	4.3920	8.4380	.2533	0	79.9000	3.8950 TO 4.8889
DF-LP	45	6.4093	7.2062	1.0749	0	41.8000	4.2721 TO 8.5465
PP	233	2.1863	5.6887	.3727	0	50.2000	1.4520 TO 2.9205
WWP	24	8.5833	14.5757	2.9759	0	66.5000	2.4273 TO 14.7394
ES	122	13.4738	20.4102	1.8473	0	106.3000	9.8155 TO 17.1321
ES-AF	475	12.1796	20.7151	.9505	0	239.8000	10.3119 TO 14.0472
WRC-WH	154	15.1435	20.1194	1.6213	0	133.5000	11.9905 TO 18.3965
WH-AF	39	8.3641	8.3074	1.3303	0	37.4000	5.6710 TO 11.0572
WL-GF-DF	498	7.8908	10.2777	.4606	0	77.5000	6.9958 TO 8.7859
WL-PP-DF	35	5.3861	5.4436	.9201	.1000	17.1000	3.5273 TO 7.2449
LPP	1015	6.0306	10.3330	.3243	0	140.0000	5.3910 TO 6.6701
WPP-LAP	236	3.1123	6.8224	.4441	0	88.0000	2.2374 TO 3.9872
HW-ASPEN	6	.6500	.9333	.3810	0	2.2000	-.3294 TO 1.6294
NONCOMM	155	4.4256	6.8727	.5463	0	62.3000	3.1489 TO 5.7024
TOTAL	4201	6.1643			0	239.8000	
UNGROUPED DATA			12.4439	.1920			6.2879 TO 7.0407
FIXED EFFECTS MODEL			12.0031	.1852			6.3013 TO 7.0274
RANDOM EFFECTS MODEL			6.6238	1.4763			3.4750 TO 9.8537

RANDOM EFFECTS MODEL - ESTIMATE OF BETWEEN COMPONENT VARIANCE 12.9175

Table 17d : Rotten 1000-hour fuel load by dominant overstory species

VARIABLE ROTTEN
BY TYPE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	13	26813.4415	2062.5724	17.1079	.0000
WITHIN GROUPS	4187	504796.7177	120.5629		
TOTAL	4200	531610.1592			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN		
DF	1110	[illegible]	9.9125	.2975	0	94.8000	6.2722	TO	7.4397
DF-LP	46	8.1430	9.1686	.9387	0	51.6000	6.1773	TO	10.1088
PP	233	4.3145	10.4042	.6450	0	111.8000	2.9452	TO	5.6847
WWP	24	10.1167	6.4793	1.3125	0	26.9000	6.3673	TO	13.8661
ES	122	13.1828	17.1142	1.5494	0	94.4000	10.1153	TO	16.2503
ES-AF	475	11.2381	14.7465	.6785	0	206.3000	9.9050	TO	12.5713
WRC-WH	154	15.0182	14.4809	1.1669	0	79.2000	13.7129	TO	18.3235
WH-AF	34	10.8255	11.0597	1.7710	0	55.3000	7.2405	TO	14.4108
WL-DF-DF	549	9.1147	10.4412	.4490	0	81.6000	8.1933	TO	10.0362
WL-PP-DF	36	5.0861	5.7428	.9571	0	32.1000	3.1430	TO	7.0292
LPP	1015	7.2450	9.4116	.2954	0	92.4000	6.6653	TO	7.8247
WBP-LAP	236	5.9691	10.6128	.6908	0	98.6000	4.6081	TO	7.3301
WW-ASPEN	6	4.5000	6.7465	2.7706	0	13.7000	-2.6218	TO	11.6218
NONCOMM	155	5.3833	6.1911	.5558	0	57.2000	4.0878	TO	6.6788
TOTAL	4201	8.0560			0	206.3000			
UNGROUPED DATA			11.2505	.1736			7.7153	TO	8.3969
FIXED EFFECTS MODEL			10.9801	.1694			7.7245	TO	8.3887
RANDOM EFFECTS MODEL			4.1419	1.1070			5.6651	TO	10.4481

RANDOM EFFECTS MODEL - ESTIMATE OF BETWEEN COMPONENT VARIANCE 7.2063

Table 17e : Total fuel load by dominant overstory species

VARIABLE TOTAL
BY TYPE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	13	167900.0515	12915.3835	42.2335	.0000
WITHIN GROUPS	4187	1280418.1543	305.8080		
TOTAL	4200	1448318.2059			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN
DF	1110	14.0847	14.5365	.4363	0	108.3000	13.2286 TO 14.9409
DF-LP	[illegible]	15.4825	14.7204	1.5374	0	62.4000	13.3264 TO 19.6387
PP	233	8.2300	12.3032	.8060	0	112.3000	6.6420 TO 9.8181
WWP	24	21.1500	20.4609	4.2582	0	93.8000	12.3412 TO 29.9588
ES	122	30.1598	26.8430	2.4303	0	123.2000	25.3485 TO 34.9712
ES-AF	475	26.3251	27.0582	1.2415	0	256.0000	23.8855 TO 28.7646
WRC-WH	154	35.8935	27.4832	2.2147	.3000	179.0000	31.5182 TO 40.2688
WH-AF	39	21.7667	15.2319	2.4390	0	56.5000	16.8291 TO 26.7042
WL-GF-DF	509	20.6839	15.1372	.6709	.1000	98.5000	19.3657 TO 22.0021
WL-PP-DF	35	13.5361	9.9528	1.5588	1.4000	48.4000	10.1686 TO 16.9037
LPP	1015	15.9200	15.2458	.4798	0	145.0000	14.9785 TO 16.8615
WPP-LPP	236	10.7691	13.8349	.9010	0	94.7000	9.0333 TO 12.5048
HW-ASPEN	5	7.2167	8.7520	3.5730	.1000	21.9000	-1.9679 TO 16.4012
NONCOMM	155	11.5199	12.3651	.9900	0	63.9000	9.5642 TO 13.4755
TOTAL	4201	17.5180			0	256.0000	
UNGROUPED DATA			15.5899	.2565			16.9563 TO 18.0797
FIXED EFFECTS MODEL			17.4474	.2699			16.9891 TO 18.0470
RANDOM EFFECTS MODEL			10.4787	2.8005			11.4673 TO 23.5682

RANDOM EFFECTS MODEL - ESTIMATE OF BETWEEN COMPONENT VARIANCE 46.7906

Table 17f : Duff layer thickness by dominant overstory species

VARIABLE DUFF
BY TYPE

ANALYSIS OF VARIANCE

SOURCE	D.F.	SUM OF SQUARES	MEAN SQUARES	F RATIO	F PROB.
BETWEEN GROUPS	13	338.2240	26.0172	30.2514	.0000
WITHIN GROUPS	4187	3600.9677	.8600		
TOTAL	4200	3939.1917			

GROUP	COUNT	MEAN	STANDARD DEVIATION	STANDARD ERROR	MINIMUM	MAXIMUM	95 PCT CONF INT FOR MEAN		
DF	1110	1.0037	.8245	.0247	0	6.5000	.9551	TO	1.0522
DF-LP	86	1.1360	.7245	.0781	0	3.7000	.9807	TO	1.2914
PP	233	.6960	.6196	.0406	0	3.9000	.6156	TO	.7765
WP	24	1.3708	1.1487	.2345	.2000	5.1000	.8858	TO	1.8559
ES	122	1.9492	1.5234	.1379	0	7.7000	1.6751	TO	2.2222
ES-AF	475	1.4597	1.1962	.0549	0	9.0000	1.3519	TO	1.5675
WRC-WH	154	1.7552	1.2981	.1046	0	7.7000	1.5485	TO	1.9619
WH-AF	39	.9256	.7066	.1132	0	2.8000	.6966	TO	1.1547
WL-GF-DF	509	1.2552	.9673	.0429	0	8.9000	1.1710	TO	1.3394
WL-PP-DF	36	.8194	.5371	.0895	.1000	2.2000	.6377	TO	1.0012
LPP	1015	1.1348	.8358	.0263	0	8.8000	1.0832	TO	1.1863
WHP-LPP	236	.7135	.6360	.0414	0	3.6000	.6320	TO	.7951
HW-ASPEN	6	.7167	.8159	.3331	0	1.9000	-.1395	TO	1.5729
NONCOMM	156	.7173	.4447	.0796	0	9.1000	.5600	TO	.8746
TOTAL	4201	1.1305			0	9.1000			
UNGROUPED DATA			.9665	.0149			1.1012	TO	1.1598
FIXED EFFECTS MODEL			.9274	.0143			1.1025	TO	1.1586
RANDOM EFFECTS MODEL			.4689	.1253			.8598	TO	1.4013

RANDOM EFFECTS MODEL - ESTIMATE OF BETWEEN COMPONENT VARIANCE .0934

APPENDIX C : WITHIN-STAND FUEL SKEWNESS STATISTICS

Table 18a : 1-hour fuel load skewness statistics

FUEL TYPE ONE HOUR

STAND	ALL DATA NPLOTS	ALL DATA X MEAN	ALL DATA X SKEW	ALL DATA LN(X+1) MEAN	ALL DATA LN(X+1) SKEW	NON-ZERO DATA NPLOTS	NON-ZERO DATA X MEAN	NON-ZERO DATA X SKEW	NON-ZERO DATA LN(X+1) MEAN	NON-ZERO DATA LN(X+1) SKEW	PRESENCE
51	10.	.208	.523	.180	.555	9.	.231	.574	.200	.758	.900
52	10.	.458	.930	.365	.785	10.	.458	.930	.365	.785	1.000
53	10.	.255	-.074	.221	-.303	9.	.284	.300	.246	.125	.900
56	10.	.515	-.535	.405	-.713	10.	.515	-.535	.405	-.713	1.000
62	10.	.239	1.295	.201	1.047	10.	.239	1.295	.201	1.047	1.000
64	10.	.447	.030	.358	-.137	10.	.447	.030	.358	-.137	1.000
65	10.	.469	1.543	.379	1.383	10.	.469	1.543	.379	1.383	1.000
84	10.	.172	1.331	.147	1.597	10.	.172	1.331	.147	1.597	1.000
85	10.	.175	.559	.150	.757	9.	.194	.770	.167	.581	.900
89	10.	.053	1.703	.050	1.532	8.	.066	1.501	.062	1.451	.800
92	10.	.325	1.253	.248	1.031	9.	.362	1.145	.276	.959	.900
93	10.	.166	1.198	.152	1.097	10.	.166	1.198	.152	1.097	1.000
94	10.	.569	.963	.505	.737	10.	.569	.963	.505	.737	1.000
0002	10.	.088	1.205	.083	1.097	10.	.088	1.205	.083	1.097	1.000
0003	20.	.114	3.005	.090	2.735	13.	.182	2.195	.138	1.997	.650
0004	20.	.130	2.635	.109	2.238	17.	.153	2.420	.129	2.073	.850
0005	20.	.145	1.542	.130	1.290	20.	.145	1.542	.130	1.290	1.000
0006	20.	.093	1.045	.085	.940	18.	.103	1.044	.096	.955	.900
0007	20.	.090	.993	.084	.554	17.	.106	.971	.099	.594	.850
0009	19.	.074	.534	.074	.441	13.	.115	.403	.108	.295	.684
0014	13.	.104	.214	.097	.148	12.	.113	.199	.105	.139	.923
0017	19.	.117	.545	.109	.756	19.	.117	.545	.109	.735	1.000
0022	20.	.113	1.795	.096	1.553	11.	.206	1.023	.174	.848	.550
0024	20.	.125	1.332	.111	1.257	18.	.138	1.320	.124	1.233	.900
0025	20.	.171	.515	.153	.531	20.	.171	.515	.153	.531	1.000
0027	20.	.064	1.027	.061	.576	17.	.075	1.193	.072	1.050	.850
0028	10.	.360	.563	.297	.425	10.	.360	.563	.297	.425	1.000
0029	20.	.123	1.835	.103	1.734	15.	.164	1.483	.137	1.354	.750
0302	10.	.142	1.755	.122	1.559	8.	.177	1.578	.153	1.457	.800
0501	10.	.308	1.555	.239	1.294	9.	.342	1.470	.266	1.277	.900
0621	10.	.143	.560	.132	.502	10.	.143	.560	.132	.502	1.000
0104	20.	.251	3.235	.208	2.705	20.	.251	3.235	.208	2.705	1.000
3027	12.	.410	1.350	.324	.930	12.	.410	1.350	.324	.930	1.000
3028	11.	.255	1.795	.200	1.457	9.	.312	1.589	.244	1.357	.818
0318	20.	.379	1.015	.295	.709	18.	.421	1.025	.329	.805	.900
0319	12.	.446	.539	.340	.315	12.	.446	.539	.340	.315	1.000
0348	14.	.277	.541	.235	.421	14.	.277	.541	.235	.421	1.000
0103	15.	.145	1.438	.130	1.209	15.	.145	1.438	.130	1.209	1.000
0104	9.	.157	.551	.141	.453	8.	.177	.582	.159	.523	.889
0105	14.	.257	2.534	.228	1.945	14.	.257	2.534	.228	1.945	1.000
0106	20.	.009	2.057	.005	2.059	4.	.043	.549	.042	.543	.200
0107	19.	.077	1.600	.070	1.350	11.	.133	1.295	.120	1.122	.579
0109	9.	.481	.395	.371	.055	9.	.481	.395	.371	.055	1.000
0004	20.	.055	2.302	.053	2.222	20.	.055	2.302	.053	2.222	1.000
0007	14.	.134	2.057	.111	1.958	14.	.134	2.057	.111	1.958	1.000
0011	9.	.197	1.475	.174	1.332	9.	.197	1.475	.174	1.332	1.000
0012	13.	.355	.519	.290	.495	13.	.355	.519	.290	.495	1.000

Table 18b : 10-hour fuel load skewness statistics

FUEL TYPE TEN HOUR

	ALL DATA					NON-ZERO DATA					
		------ X ------		--- LN(X+1) ---			------ X ------		--- LN(X+1) ---		
STAND	NPLOTS	MEAN	SKEW	MEAN	SKEW	NPLOTS	MEAN	SKEW	MEAN	SKEW	PRESENCE
51	10.	1.003	.551	.573	.199	7.	1.433	.253	.819	.011	.700
52	10.	.775	.724	.513	.391	9.	.863	.702	.570	.507	.900
58	10.	1.468	.431	.834	-.257	9.	1.553	.522	.925	.404	.900
60	10.	1.552	.251	.921	-.202	10.	1.662	.281	.921	-.202	1.000
62	10.	1.035	.191	.615	-.235	7.	1.479	.401	.879	.058	.700
64	10.	.905	.299	.558	-.051	8.	1.132	.192	.709	-.091	.800
65	10.	1.003	.545	.554	.279	10.	1.003	.545	.554	.279	1.000
84	10.	.712	.709	.437	.409	6.	1.186	.253	.728	.085	.600
85	10.	.935	.035	.514	-.414	9.	1.042	.139	.683	-.245	.900
89	10.	1.518	.147	.820	-.245	8.	2.022	-.039	1.025	-.453	.800
92	10.	1.294	.531	.713	.121	9.	1.436	.455	.792	.100	.900
93	10.	1.058	1.075	.646	.248	9.	1.186	1.154	.720	.503	.900
94	10.	1.565	.565	.892	.022	10.	1.565	.565	.892	.022	1.000
0002	10.	.424	1.454	.335	.942	9.	.477	1.725	.372	1.518	.900
0003	20.	.335	2.755	.215	1.534	8.	.836	1.599	.539	1.309	.400
0004	20.	.547	1.047	.388	.418	15.	.729	1.225	.518	.851	.750
0005	20.	.545	1.979	.355	.952	12.	.908	1.798	.591	1.175	.600
0006	20.	.599	1.057	.372	.672	11.	1.073	.534	.576	.319	.550
0007	20.	.491	.555	.349	.294	13.	.756	.311	.537	.159	.650
0009	19.	.655	1.549	.395	.572	11.	1.129	1.113	.682	.734	.579
0014	13.	.355	1.535	.253	1.002	8.	.576	1.529	.427	1.348	.615
0017	19.	.728	1.115	.451	.359	12.	1.146	1.146	.715	.509	.632
0022	20.	.775	1.359	.417	.959	11.	1.409	.555	.758	.340	.550
0024	20.	.914	1.194	.501	.612	12.	1.523	.761	.836	.350	.600
0025	20.	.745	2.525	.435	1.020	12.	1.242	2.243	.725	1.505	.600
0027	20.	.453	.555	.318	.325	10.	.917	.380	.535	-.129	.500
0028	10.	.802	1.544	.443	.974	6.	1.337	1.086	.738	.841	.600
0029	20.	.610	1.333	.363	.573	10.	1.220	.533	.726	.307	.500
0002	10.	1.001	-.230	.570	-.494	10.	1.001	-.230	.570	-.494	1.000
0501	10.	.762	-.225	.531	-.458	9.	.847	-.215	.590	-.364	.900
0421	10.	.635	1.204	.435	.550	8.	.794	1.270	.543	.933	.800
0104	20.	.890	1.075	.551	.309	16.	1.112	1.119	.689	.515	.800
0027	12.	1.363	-.159	.779	-.500	11.	1.487	-.247	.850	-.575	.917
0028	11.	1.378	.612	.759	.148	10.	1.516	.512	.834	.272	.909
0308	20.	.990	1.101	.574	.222	14.	1.415	1.137	.820	.348	.700
0318	12.	1.351	.592	.745	.040	10.	1.620	.733	.894	.457	.833
0348	18.	1.319	2.454	.625	.795	16.	2.047	2.377	.931	.995	.889
0103	15.	.702	.373	.470	-.024	11.	.958	.333	.640	-.090	.733
0104	9.	.933	1.344	.583	.970	9.	.933	1.344	.583	.970	1.000
0105	19.	.743	2.473	.446	1.058	13.	1.086	2.252	.652	1.525	.684
0106	20.	.044	3.924	.034	3.924	1.	.872	0.	.579	0.	.050
0107	19.	.415	1.725	.250	1.356	7.	1.130	.473	.680	.232	.368
0109	9.	1.334	.535	.734	-.053	7.	1.716	.538	.944	.543	.778
0004	20.	2.352	1.223	1.133	.092	20.	2.352	1.223	1.133	.092	1.000
0007	14.	.754	1.919	.415	1.409	10.	1.055	1.470	.585	1.251	.714
0011	9.	.941	1.050	.505	.210	8.	1.059	1.308	.530	.302	.889
0012	13.	1.577	.814	.856	-.213	12.	1.708	1.011	.938	.257	.923

Table 18c : 100-hour fuel load skewness statistics

FUEL TYPE 100 HOUR

	ALL DATA					NON-ZERO DATA					
		------ X ------		--- LN(X+1) ---			------ X ------		--- LN(X+1) ---		
STAND	NPLOTS	MEAN	SKEW	MEAN	SKEW	NPLOTS	MEAN	SKEW	MEAN	SKEW	PRESENCE
51	10.	1.157	1.674	.433	1.200	3.	3.889	.385	1.444	.385	.300
52	10.	1.351	.312	.594	-.151	6.	2.250	1.361	1.154	1.351	.600
53	10.	.553	.745	.324	.745	3.	1.944	0.	1.080	0.	.300
60	10.	2.917	.959	1.045	.050	7.	4.167	.721	1.493	.559	.700
62	10.	1.555	.593	.575	.314	5.	3.111	.504	1.350	.485	.500
64	10.	2.134	.279	.684	-.110	6.	3.563	.174	1.474	-.128	.600
55	10.	2.139	-.151	.959	-.455	7.	3.055	-.229	1.370	-.229	.700
44	10.	.775	1.915	.300	1.550	2.	3.889	0.	1.501	.000	.200
45	10.	1.351	.903	.510	.781	3.	4.537	.385	1.699	.385	.300
49	10.	.778	.349	.432	.349	4.	1.944	0.	1.080	0.	.400
42	10.	1.351	1.237	.524	.356	5.	2.722	1.073	1.248	1.073	.500
43	10.	2.134	1.035	.758	.501	5.	4.278	.292	1.517	.292	.500
94	10.	1.157	.552	.591	.152	5.	2.333	1.073	1.181	1.073	.500
0002	10.	6.792	.170	1.805	-.615	9.	7.547	.148	2.005	-.451	.900
0003	20.	.594	1.617	.240	1.516	3.	3.957	.384	1.501	.384	.150
0004	20.	1.914	1.937	.595	1.010	7.	5.469	.757	1.599	.332	.350
0005	20.	1.336	1.290	.560	.575	8.	3.345	.580	1.399	.568	.400
0006	20.	.904	3.079	.342	1.594	5.	3.617	1.073	1.368	1.071	.250
0007	20.	1.306	1.534	.520	.632	7.	3.732	.940	1.486	.493	.350
0009	19.	.636	2.451	.277	1.547	4.	3.021	.749	1.318	.747	.211
0014	13.	2.894	1.153	.775	.555	5.	7.525	.204	2.017	-.328	.385
0017	19.	1.388	1.217	.585	.501	8.	3.297	.587	1.339	.597	.421
0022	20.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0024	20.	4.502	.573	1.232	-.120	12.	7.504	.398	2.054	.173	.600
0025	20.	2.409	.403	.559	.149	10.	4.816	-.398	1.717	-.552	.500
0027	20.	.399	1.044	.435	.724	7.	2.567	.732	1.245	.719	.350
0028	10.	2.325	1.757	.813	.718	5.	5.655	.378	1.627	.614	.500
0029	20.	1.319	2.375	.420	1.455	5.	5.277	.544	1.582	.273	.250
0602	10.	.603	.753	.331	.748	3.	2.011	.385	1.102	.385	.300
0601	10.	.809	1.251	.324	1.251	2.	4.044	.000	1.618	.000	.200
0821	10.	.413	1.255	.224	1.253	2.	2.064	0.	1.119	.000	.200
0104	20.	.724	1.347	.361	.945	6.	2.413	1.317	1.205	1.291	.300
0027	12.	4.551	.795	1.358	-.252	9.	6.067	.748	1.811	.187	.750
0025	11.	1.557	.555	.785	.050	6.	3.424	.475	1.439	.251	.545
0308	20.	1.494	1.033	.526	.459	9.	3.319	.531	1.397	.395	.450
0318	12.	2.324	.695	.967	.110	7.	4.550	.643	1.658	.243	.583
0348	18.	3.925	1.592	1.209	.027	13.	5.434	1.314	1.674	.711	.722
0103	15.	4.518	.607	1.558	-.575	14.	4.940	.433	1.570	.330	.933
0104	9.	4.725	-.112	1.345	-.355	6.	7.088	-.331	2.017	-1.103	.667
0105	19.	2.424	.825	.847	.323	10.	4.616	.143	1.609	.057	.526
0105	20.	.755	1.338	.343	1.154	5.	3.142	-.292	1.393	-.292	.250
0107	19.	.922	1.704	.343	1.456	4.	4.380	-.319	1.526	-.449	.211
0109	9.	2.959	1.235	.935	.315	5.	5.345	.743	1.683	.383	.555
0004	20.	2.572	.325	1.075	-.533	15.	3.429	.727	1.435	.453	.750
0007	14.	1.503	.554	.737	.229	7.	3.506	.315	1.475	.057	.500
0011	9.	3.304	.305	1.125	-.156	6.	4.963	-.024	1.537	-.197	.667
0012	13.	4.499	1.453	1.374	-.315	10.	5.549	1.593	1.786	.703	.769

Table 18d : Sound 1000-hour fuel load skewness statistics

FUEL TYPE SOUND

	ALL DATA					NON-ZERO DATA					
		X		LN(X+1)			X		LN(X+1)		
STAND	NPLOTS	MEAN	SKEW	MEAN	SKEW	NPLOTS	MEAN	SKEW	MEAN	SKEW	PRESENCE
51	10.	.787	2.139	.285	1.797	2.	3.934	.000	1.423	.000	.200
52	10.	1.745	.615	.061	.524	5.	3.541	-.135	1.321	-.282	.500
58	10.	.157	2.277	.095	2.277	1.	1.573	0.	.945	0.	.100
60	10.	.444	.452	.297	.407	4.	1.109	.075	.742	.054	.400
62	10.	.459	1.559	.257	1.422	3.	1.565	.365	.857	.340	.300
64	10.	.165	1.194	.129	1.045	3.	.550	.385	.431	.385	.300
65	10.	1.114	.615	.570	.411	6.	1.857	-.027	.949	-.083	.500
84	10.	2.546	1.185	.641	.926	3.	8.486	-.329	2.136	-.353	.300
85	10.	.934	2.277	.234	2.277	1.	9.336	0.	2.336	0.	.100
89	10.	.199	1.659	.135	1.520	2.	.993	0.	.574	0.	.200
92	10.	.158	1.923	.115	1.753	2.	.836	.000	.581	.000	.200
93	10.	.730	1.745	.365	1.187	4.	1.825	.501	.912	.443	.400
94	10.	.436	2.277	.155	2.277	1.	4.359	0.	1.679	0.	.100
0002	10.	4.183	.153	1.607	-.118	10.	4.183	.153	1.607	-.118	1.000
0003	20.	.553	3.524	.049	3.524	1.	1.551	0.	.975	0.	.050
0004	20.	.021	3.824	.017	3.824	1.	.418	0.	.349	0.	.050
0005	20.	1.475	1.439	.515	.579	10.	2.952	.763	1.230	.129	.500
0006	20.	.065	2.476	.051	2.470	2.	.657	.000	.505	0.	.100
0007	20.	.275	2.000	.154	1.809	4.	1.377	-.185	.820	-.302	.200
0009	19.	.322	3.502	.114	3.510	2.	3.063	.000	1.128	0.	.105
0014	13.	.708	.750	.429	.395	7.	1.315	.319	.797	-.019	.538
0017	19.	.045	3.095	.033	3.095	1.	.580	0.	.531	0.	.053
0022	20.	.055	3.824	.042	3.824	1.	1.297	0.	.832	0.	.050
0024	20.	1.513	2.131	.518	1.181	7.	4.323	.322	1.479	.450	.350
0025	20.	2.159	2.015	.756	.551	11.	3.979	1.423	1.375	.195	.550
0027	20.	1.081	.991	.470	.824	7.	3.089	-.534	1.343	-.945	.350
0028	10.	.814	1.227	.433	.815	5.	1.629	.462	.855	.299	.500
0029	20.	.227	2.540	.129	2.342	3.	1.514	-.171	.857	-.257	.150
0002	10.	.177	.840	.139	.812	3.	.590	-.365	.462	-.367	.300
0501	10.	.302	1.125	.202	1.042	3.	1.005	-.384	.572	-.384	.300
0321	10.	.325	1.123	.213	1.034	3.	1.085	-.384	.709	-.384	.300
0104	20.	2.409	.429	1.054	-.454	16.	3.012	.511	1.317	.223	.800
0027	12.	11.503	2.303	1.393	.350	11.	12.550	2.174	2.055	.709	.917
0028	11.	2.307	1.525	.763	.558	6.	4.230	.512	1.398	.153	.545
0309	20.	3.292	3.515	.555	1.419	7.	9.407	1.574	1.872	1.154	.350
0319	12.	4.419	.775	1.113	.253	7.	7.576	.129	1.908	-.397	.583
0349	18.	2.219	1.549	.551	.552	7.	5.705	.428	1.700	-.249	.389
0103	15.	12.372	-.174	2.455	-.481	15.	12.372	-.174	2.466	-.481	1.000
0104	9.	3.939	.353	2.033	-1.007	8.	10.112	.503	2.287	-.144	.889
0105	19.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0106	20.	.240	3.541	.109	3.295	2.	2.397	-.000	1.086	.000	.100
0107	19.	4.555	1.255	1.207	-.031	11.	7.860	1.523	2.085	.540	.579
0109	9.	.131	2.074	.107	2.074	1.	1.520	0.	.960	0.	.111
0004	20.	1.324	.871	.579	.558	9.	2.952	-.124	1.288	-.553	.450
0007	14.	2.924	2.675	.575	1.574	5.	8.185	.954	1.512	.355	.357
0011	9.	2.325	.483	1.170	-.350	8.	3.179	.317	1.316	-.152	.889
0012	13.	1.508	2.505	.435	1.777	5.	4.072	.924	1.139	.569	.385

Table 18e : Rotten 1000-hour fuel load skewness statistics

FUEL TYPE ROTTEN

	ALL DATA					NON-ZERO DATA					
		------ X ------		--- LN(X+1) ---			------ X ------		--- LN(X+1) ---		
STAND	NPLOTS	MEAN	SKEW	MEAN	SKEW	NPLOTS	MEAN	SKEW	MEAN	SKEW	PRESENCE
51	10.	1.595	1.550	.453	1.324	2.	9.479	.000	2.316	0.	.200
52	10.	.034	2.277	.033	2.277	1.	.387	0.	.327	0.	.100
55	10.	.505	1.520	.309	1.057	5.	1.012	.713	.516	.412	.500
60	10.	.514	.930	.344	.532	5.	1.032	.535	.655	.259	.500
62	10.	1.355	1.655	.555	.549	5.	2.730	.554	1.130	.324	.500
64	10.	.717	1.255	.429	.545	5.	1.194	.555	.715	.454	.500
65	10.	.234	.544	.153	.455	4.	.564	-.153	.456	-.219	.400
84	10.	3.303	.634	1.056	.023	5.	5.504	.304	1.750	-.203	.500
85	10.	1.710	.821	.545	.732	4.	4.275	-.559	1.485	-.591	.400
89	10.	.413	1.315	.224	1.293	2.	2.066	.000	1.118	.000	.200
92	10.	2.391	.420	.925	-.057	6.	3.985	.219	1.542	-.153	.600
93	10.	3.546	1.041	1.210	.152	9.	4.051	.947	1.344	.150	.900
94	10.	.105	1.295	.055	1.290	2.	.526	-.000	.423	.000	.200
0002	10.	.224	.465	.182	.357	5.	.449	-.281	.364	-.283	.500
0003	20.	1.227	1.591	.445	1.238	6.	4.091	.467	1.484	-.117	.300
0004	20.	1.526	1.673	.568	1.159	11.	2.774	.525	1.028	.580	.550
0005	20.	1.237	1.913	.500	1.094	9.	2.748	.904	1.110	.214	.450
0006	20.	2.185	2.215	.807	.722	14.	3.122	1.510	1.152	.535	.700
0007	20.	1.522	1.553	.546	1.052	10.	3.044	.924	1.093	.159	.500
0009	19.	1.149	3.052	.407	1.715	7.	3.119	1.405	1.104	.707	.368
0014	13.	1.055	1.155	.544	.512	7.	1.977	.745	1.010	.389	.538
0017	19.	1.176	2.221	.398	1.493	6.	3.705	.587	1.261	-.143	.315
0022	20.	.404	1.605	.249	1.451	5.	1.550	.171	.995	.081	.250
0024	20.	.569	1.951	.355	1.351	10.	1.338	1.053	.711	.595	.500
0025	20.	.594	2.755	.405	1.550	9.	1.966	1.583	.900	1.171	.450
0027	20.	.596	.953	.477	.551	10.	1.793	.315	.955	-.185	.500
0028	10.	.266	.855	.207	.620	5.	.532	.573	.413	.549	.500
0029	20.	.493	2.805	.207	2.151	3.	3.287	.355	1.379	.325	.150
0002	10.	.779	1.793	.305	1.473	2.	3.897	.000	1.527	.000	.200
0501	10.	.760	.825	.349	.705	4.	1.900	-.445	.997	-.505	.400
0821	10.	.376	1.094	.250	.654	4.	.939	.117	.625	-.118	.400
0104	20.	1.419	.354	.599	-.008	12.	2.365	.034	1.165	-.532	.600
0027	12.	2.052	1.435	.853	.164	9.	2.749	1.346	1.177	.290	.750
0028	11.	.336	2.344	.170	2.134	2.	1.861	-.000	.934	-.000	.182
0309	20.	.044	2.470	.037	2.470	2.	.441	.000	.365	.000	.100
0319	12.	1.234	2.455	.404	1.720	4.	3.703	.715	1.212	.576	.333
0349	18.	.753	1.952	.317	1.618	5.	2.740	.178	1.141	-.025	.278
0103	15.	1.247	1.034	.604	.531	9.	2.078	.519	1.007	.255	.600
0104	9.	2.572	1.592	.955	.310	6.	4.008	1.254	1.432	.915	.667
0105	19.	1.555	2.405	.307	2.376	2.	17.520	.000	2.921	-.000	.105
0106	20.	1.430	3.253	.365	1.957	4.	7.152	.591	1.624	.425	.200
0107	19.	.478	2.553	.238	1.691	5.	1.515	.554	.897	.308	.263
0109	9.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0004	20.	3.113	1.052	1.523	-.114	12.	13.522	.989	2.538	.142	.600
0007	14.	4.327	1.355	.590	1.215	4.	15.143	-.498	2.416	-.701	.286
0011	9.	1.210	1.237	.587	.526	5.	2.178	.781	1.056	.555	.555
0012	13.	1.367	2.545	.434	1.592	4.	4.507	.721	1.412	.512	.308

Table 18f : Duff layer thickness skewness statistics

FUEL TYPE DUFF DEPTH

	ALL DATA					NON-ZERO DATA					
		------ X ------		--- LN(X+1) ---			------ X ------		--- LN(X+1) ---		
STAND	NPLOTS	MEAN	SKEW	MEAN	SKEW	NPLOTS	MEAN	SKEW	MEAN	SKEW	PRESENCE
51	10.	1.990	1.142	.986	.887	10.	1.990	1.142	.986	.887	1.000
52	10.	1.505	-.037	.882	-.215	10.	1.505	-.037	.882	-.215	1.000
53	10.	1.535	-.148	.924	-.355	10.	1.535	-.148	.924	-.355	1.000
60	10.	1.750	.283	.978	-.082	10.	1.750	.283	.978	-.082	1.000
62	10.	2.395	1.844	1.152	1.301	10.	2.395	1.844	1.152	1.301	1.000
64	10.	2.170	-.752	1.140	-.855	10.	2.170	-.752	1.140	-.855	1.000
65	10.	2.415	1.430	1.151	.875	10.	2.415	1.430	1.151	.875	1.000
44	10.	.495	.154	.457	-.352	8.	.619	.340	.583	.423	.800
45	10.	.990	2.120	.525	1.510	10.	.990	2.120	.525	1.510	1.000
49	10.	.790	1.342	.535	.934	10.	.790	1.342	.535	.934	1.000
92	10.	.510	.295	.435	-.000	9.	.567	.348	.480	.151	.900
93	10.	1.280	1.740	.754	1.257	10.	1.280	1.740	.754	1.257	1.000
94	10.	1.350	.515	.778	.155	10.	1.350	.515	.778	.155	1.000
0002	10.	1.570	-.791	.959	-.983	10.	1.570	-.791	.959	-.983	1.000
0003	20.	.535	3.207	.328	2.028	16.	.669	2.850	.410	1.954	.800
0004	20.	.698	1.959	.419	1.052	19.	.734	1.898	.441	1.004	.950
0005	20.	1.448	.335	.865	-.494	19.	1.524	.449	.910	-.315	.950
0006	20.	.800	.355	.531	-.004	19.	.842	.324	.559	-.030	.950
0007	20.	1.258	.315	.705	-.052	19.	1.324	.252	.744	-.105	.950
0009	19.	.524	1.749	.433	1.005	19.	.524	1.749	.433	1.005	1.000
0014	13.	.519	.271	.457	.109	13.	.519	.271	.457	.109	1.000
0017	19.	1.505	1.451	.859	.234	19.	1.505	1.451	.859	.234	1.000
0022	20.	.780	1.204	.483	.840	19.	.821	1.154	.508	.522	.950
0024	20.	.915	.575	.522	-.017	20.	.915	.575	.522	-.017	1.000
0025	20.	1.565	.770	.904	-.455	20.	1.565	.770	.904	-.455	1.000
0027	20.	1.358	.357	.735	-.108	19.	1.429	.304	.777	-.175	.950
0028	10.	1.170	1.130	.545	.317	10.	1.170	1.130	.545	.317	1.000
0029	20.	.825	1.024	.538	.444	19.	.868	1.025	.566	.493	.950
0002	10.	1.570	.203	.877	-.533	10.	1.570	.203	.877	-.533	1.000
0501	10.	1.360	.580	.791	.377	10.	1.360	.580	.791	.377	1.000
0421	10.	.230	-.009	.199	-.157	9.	.256	-.043	.222	-.218	.900
0104	20.	2.043	-.004	1.075	-.479	20.	2.043	-.004	1.075	-.479	1.000
0027	12.	5.588	.155	1.765	-.174	12.	5.588	.155	1.765	-.174	1.000
0028	11.	1.500	.770	.849	.317	11.	1.500	.770	.849	.317	1.000
0304	20.	1.580	.560	.890	.092	20.	1.580	.560	.890	.092	1.000
0319	12.	1.500	.912	.865	.395	12.	1.500	.912	.865	.395	1.000
0349	18.	1.547	1.381	.838	.303	18.	1.547	1.381	.838	.303	1.000
0103	15.	3.950	1.197	1.555	-.079	15.	3.950	1.197	1.555	-.079	1.000
0104	9.	2.581	.831	1.315	.551	9.	2.581	.831	1.315	.551	1.000
0105	19.	2.163	1.903	1.057	.058	18.	2.283	2.135	1.115	.953	.947
0106	20.	.759	1.955	.443	1.009	15.	1.013	1.569	.590	.554	.750
0107	19.	1.705	.527	.913	-.324	19.	1.705	.527	.913	-.324	1.000
0109	9.	.472	-.112	.379	-.192	9.	.472	-.112	.379	-.192	1.000
0004	20.	1.258	.257	.749	-.202	20.	1.258	.257	.749	-.202	1.000
0007	14.	.557	.062	.426	-.122	14.	.557	.062	.426	-.122	1.000
0011	9.	3.744	1.079	1.379	.545	9.	3.744	1.079	1.379	.545	1.000
0012	13.	.269	1.073	.206	.998	10.	.350	.737	.257	.598	.769